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ENERGY MONITORING AND CONTROL SYSTEM (EMCS) APPLICATION STUDY

VOL 1
GENERAL APPLICATIONS

NEWCOMB AND BOYD CONSULTING ENGINEERS
ATLANTA, GEORGIA

JULY 1978

Final Report For Period February 1977 to February 1978

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An Energy Monitoring and Control System (EMCS) Application Study was performed to develop general procedures to analyze and economically prioritize EMCS functions, and to develop outline performance specifications for possible use in future USAF EMCS acquisition. The study is explained in a two volume report. Volume I contains the development of the study, inclusion and recommendation, and analysis techniques for determining cost and savings for each EMCS system/function. Volume II contains a computerized analysis (con't)

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system. It provides an overall analysis system description, individual program descriptions, input instructions, sample input and output, and FORTRAN source listings of all programs.

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PREFACE

This report was prepared by Newcomb and Boyd Consulting Engineers under Contract No. 708635-77C-106. The effort described by this report was accomplished during the period of February 1977 through February 1978 and was funded under the Investigational Engineering Program.

Mr. Steve Bruning was Newcomb & Boyd's project coordinator. He was aided by Warren Shiver and Ron Creswell in the writing of the report. The Air Force Civil Engineering Center project officers were Capt Jon M. Davis, Mr. Freddie L. Beason, and Mr. Larry W. Strother.

The assistance of HQ TAC/DE, HQ SAC/DE, Homestead AFB/DE, Fairchild AFB/DE, and Grand Forks AFB/DE is greatly appreciated and contributed significantly to the accomplishment of this effort.

This report has been reviewed by the Information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This report has been reviewed and is approved for publication.

LARRY W. STROTHER
Project Officer

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1.0 GENERAL EMCS APPLICATION STUDY

1.1 INTRODUCTION

The objectives of the Energy Monitoring and Control System (EMCS) Application Study are to 1) perform feasibility studies of Homestead AFB, Fla., Fairchild AFB, Wash., and Grand Forks AFB, N.D. to determine optimum EMCS configurations for these Bases, 2) develop general procedures to analyze and economically prioritize EMCS functions, and 3) use the results of steps 1 and 2 to develop outline performance specifications for use in future USAF acquisition of EMC systems. This work has been accomplished in two phases. The first phase consisted of the feasibility studies of two of the selected bases along with accompanying engineering description and documentation. The second phase consists of generalization of the procedures used in Phase I, testing of these procedures on one additional installation, and preparation of a resulting outline specification.

Both phases of the project have been completed and the results are reported herein.

A properly designed EMCS gives the BCE the ability to monitor and control a wide variety of points within his facilities. This report looks only at functions which directly reduce energy consumption. It should be noted that operations and maintenance functions may be equally important to the BCE.

1.2 BACKGROUND

Over the past thirty years, Energy Monitoring and Control Systems (EMCS) have undergone an evolutionary process. To understand the current Air Force EMCS situation, a brief review of that evolution is needed.

The early forerunners of modern EMCS were the hardwired central panel banks common in large buildings of thirty years ago. These central panel banks were connected via individual wires or pneumatic tubing to sensors and controllers throughout a large structure. The main purpose of the panels was to monitor temperatures, pressures, etc., from a central location. This location was generally the building engineer's office. Because of the method of gathering data, that is, individual wires or tubing to each point, these systems were generally only used in large single building installations. These panels offered little control over the equipment which they monitored other than the starting and stopping of that equipment.

The next step in the evolutionary process was the development of "smart" central equipment. The central processing unit (CPU) of these systems was actually hardwired logic circuits. One of the main differences between these systems and their predecessors was that these systems could digitally display temperatures and pressures instead of using gauges and dials. These systems also contained a memory where historical data could be stored. The primary purpose of these systems was to report alarms and monitor temperatures and pressures throughout a building. The only common control features of these systems were time schedule start-stop and manual temperature control point adjustment. Programming of the machine was limited strictly to whatever fixed circuitry a manufacturer had developed for the specific machine.

A significant improvement in the performance of the hardwired logic units resulted from the combination of these units with a multiplexed transmission system. In such a transmission system, individual sensors

and controllers were wired to a concentrator field panel installed near the sensor locations. At the field panel the signals were converted to digital form and multiplexed to the CPU. This system required the installation of only a two or four wire cable from the CPU to concentrator panels in mechanical rooms throughout a building instead of the many multi-conductor cables necessary for previously described systems of this type. Once this configuration of system was developed, the first multi-building complexes began to apply the concept of central monitoring and control. This system was common on college campuses and was used in early Air Force EMCS installations.

Another major improvement in system flexibility and performance was replacement of the hardwired logic CPU with a general purpose minicomputer. This step allowed the manufacturers easy programming of the systems, easy modification of the systems, and greater flexibility in using the monitored information. Through software, the manufacturers could monitor data, perform calculations with the collected data, and use the results of those calculations to send commands to field controllers or sound alarms. Although the application of general purpose computers made programming easy for the manufacturer, they did not pass this flexibility on directly to the customer. Most purchasers of these systems were interested in the operations the systems performed and not in how they performed those operations. As a result of this approach, from the customer's standpoint, a major project was required to add a single point to the system, to change constants related to a point, or to add specialized programs to the computer software library. In general, only the original manufacturer was capable of performing these actions, thus resulting in a non-competitive procurement situation.

The above evolution generally describes the process with which major conventional controls manufacturers developed the systems they are marketing today. A different group of manufacturers has appeared on the scene within the past five years. These manufacturers are generally smaller firms with backgrounds in process control applications or general computer systems applications, instead of a conventional con-

trols background. Their approach has been to use off-the-shelf computer, transmission, and sensor components. The components are combined with proprietary software to form an EMCS. These manufacturers claim to provide greater flexibility and adaptability to the owner of an EMCS for less cost. Their main support for this argument is that their systems generally allow the owner to take advantage of the full computer capability without having to retain the manufacturer. This flexibility allows the owner to write programs, modify existing programs, and retrieve monitored data, which is not possible with most of the major conventional control manufacturers' systems. This competition is now causing a re-evaluation of the system design philosophy of the major control manufacturers.

The Air Force has been involved in all stages of the evolutionary process described above. Many large individual buildings, such as hospitals, contain the hardwired central panel systems that were the initial forerunners of the EMCS. These applications were generally limited to individual buildings. The first Base-wide systems which instrumented multiple buildings were procured when the multiplexed transmission system in conjunction with the hard logic CPU became available. At that time the principal justification for procurement of such systems was the monitoring of equipment to reduce manpower requirements. Minimal control was available or emphasized in these early projects. The installations attained varied operational success, but virtually all of the systems failed in the manpower reduction objective. During the first few months of system operation, a concentrated effort by the manufacturer was necessary to de-bug the system before acceptance by the Air Force. Once these systems were accepted, they slowly decayed for several reasons. This decay could easily be observed in the inaccurate operation or failure of the field sensors. This process continued until base personnel generally lost confidence in the system.

The energy crisis and the advent of computer based systems brought new interest and direction to central control applications. The rapid rise of energy costs, coupled with the increased system capability to reduce energy consumption, has improved the economic feasibility of energy monitoring and control system application. Although the systems have not reduced manpower as expected, some manpower savings are possible and will be realized. More importantly, the energy conserving control aspects of the system are of such value that, in long range terms, they can be justified on that basis alone.

As described above, central control systems have evolved from systems whose principle value was the monitoring of points, to systems whose principle value is the control of equipment. Because of this process of evolution, with its inherent inertia, problems have occurred. The engineering design process has not kept pace with the change in purpose of the EMCS from monitoring to control. Many recently installed systems include a number of points whose only purpose is monitoring of equipment and which effect no direct energy savings. Generally, insufficient funds are available at one time to purchase this full capability for every building on an Air Force Base. The result of this limitation is that a reduced system is procured by not connecting some or many of the buildings on a given Base. This approach results in the selection of many monitoring functions with no associated energy savings in one building, while another building is not connected to the EMCS at all. An alternative to this approach is to delete monitoring points from the first building and connect energy conserving points, or energy control points in the second building. Whether or not to delete monitoring points is a decision of management that has to be looked at on an individual basis based on past experience.

Generally, the design philosophy within the Air Force EMCS program has enlarged to include the energy conscious approach. Systems now under design are being configured on the basis of energy savings as well as O&M functions. A number of complex problems involved in determining the optimum configuration of an EMCS for a particular Base

have been defined as a result of this enlargement in design philosophy. The complexity of the problems stems from the inter-relationship of costs to perform alternative EMCS activities. One of the primary purposes of this study is to examine these analysis problems and to develop a procedure to solve them.

1.3 EMCS DEFINITION

Before an in-depth study of EMCS applications can be undertaken, it is necessary to define an EMCS. This is necessary to identify the problems which are encountered in the design analysis of such a system.

Based on the current Air Force design philosophy, the primary purpose of an EMCS is to effect reduced energy consumption and thus reduce energy related operating expenses. This goal is accomplished by exercising control over the energy consuming systems. Many different EMCS configurations are available which will accomplish these goals. Common to all of the systems, as indicated in Figure No. I, is the requirement to transfer data from remote areas to a central location. At the central location, the data from the remote locations are displayed, analyzed, compared to and combined with other current and historical data gathered and maintained by the EMCS. Based on this information, in conjunction with operator decisions, and automatic preprogrammed activities, control decisions are made. Following the decision making process, instructions are transmitted to actuators which react as required to satisfy the instructions.

Because this is a study of Air Force EMCS applications, only those configurations applicable to Air Force installations will be considered. Generally an Air Force EMCS will consist of a central control center, a data transmission system between the central control system and each of the buildings connected to the EMCS, and sensors and actuators with their related equipment located in each building connected to the EMCS. The central control center is normally located in the Base Civil Engineer's Office near the work desk area which is manned 24 hours per day.

The transmission system is designed to transmit data between individual buildings (generally dispersed over a large geographical area) and the Central Control Center.

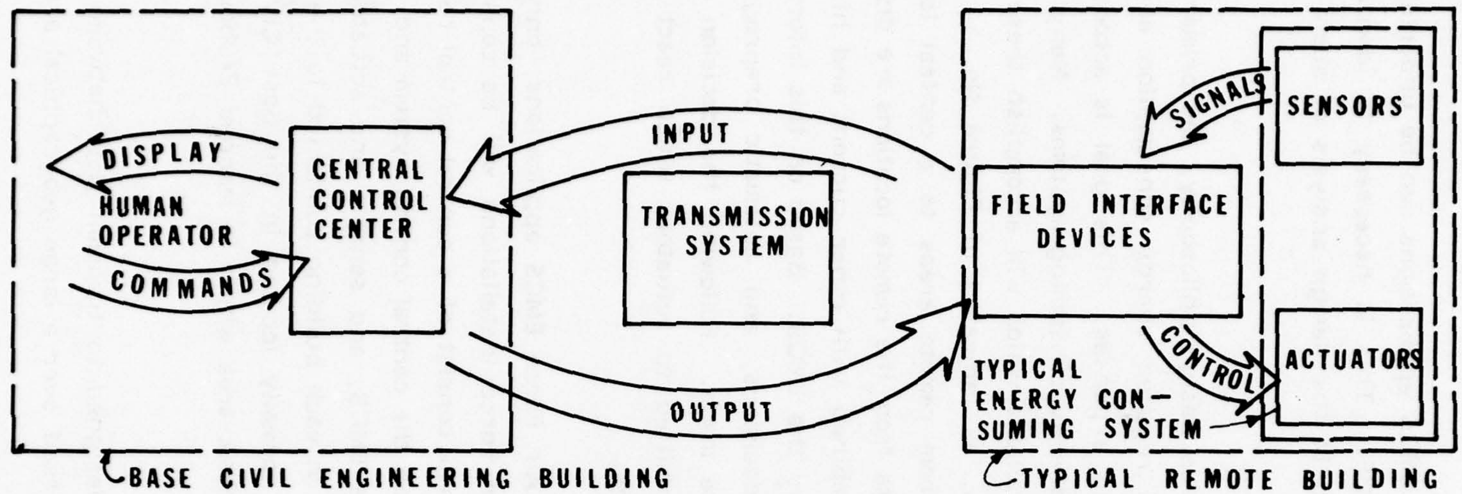


FIGURE 1 - EMCS INFORMATION TRANSFER

The field equipment (sensors and actuators) must be designed to interface with existing energy consuming systems of varying size, age, and operating condition. Only in a very few instances has the EMCS field equipment been designed and installed as an original part of the system to which it is connected.

As shown in Figure No. 2, the basic components of the central control center include a computer, a system control console, a mass storage device (usually a disk), a hard copy output device, and a communications multiplexer/controller. The computer controls all central control center devices, processes data, executes programs and interprets commands. The system control console is used by the operator to communicate with the EMCS. The mass storage device is used to store information that is not currently being utilized by the computer. When a permanent copy of an alarm or a report is desired by the operator, the hard copy output device is used for this function. The communications multiplexer/controller provides the interface between the central control center and the data transmission system. The multiplexer/controller controls input and output information received from the various data transmission system components.

The data transmission system may be of varied configurations and consist of several different components. Among the methods used to transfer data between the central control center and the remote buildings are leased or government furnished telephone lines, specially installed dedicated signal lines, radio transmission, and microwave transmission. Many different methods and design philosophies are associated with each of these types of data transfer. At this time, none of the EMCS manufacturers use exactly the same transmission methods and protocols.

To interface with the transmission system and subsequently the central control center, a remote building must be connected through at least one field interface device (FID). This device, as shown in Figure No. 3, includes the electronic equipment necessary to receive and send information over the specific transmission system, to receive signals

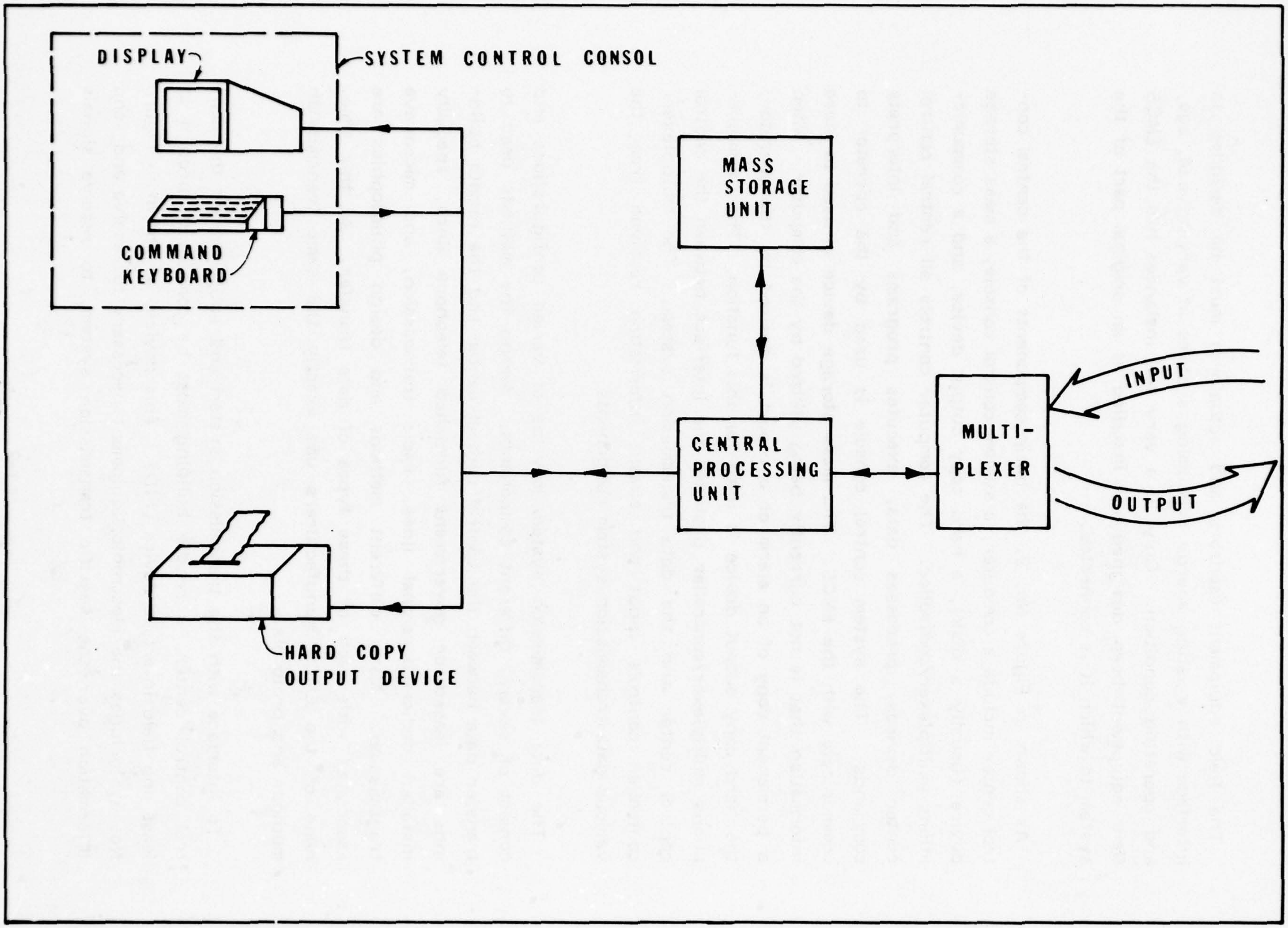


FIGURE 2 - CENTRAL CONTROL CENTER CONFIGURATION

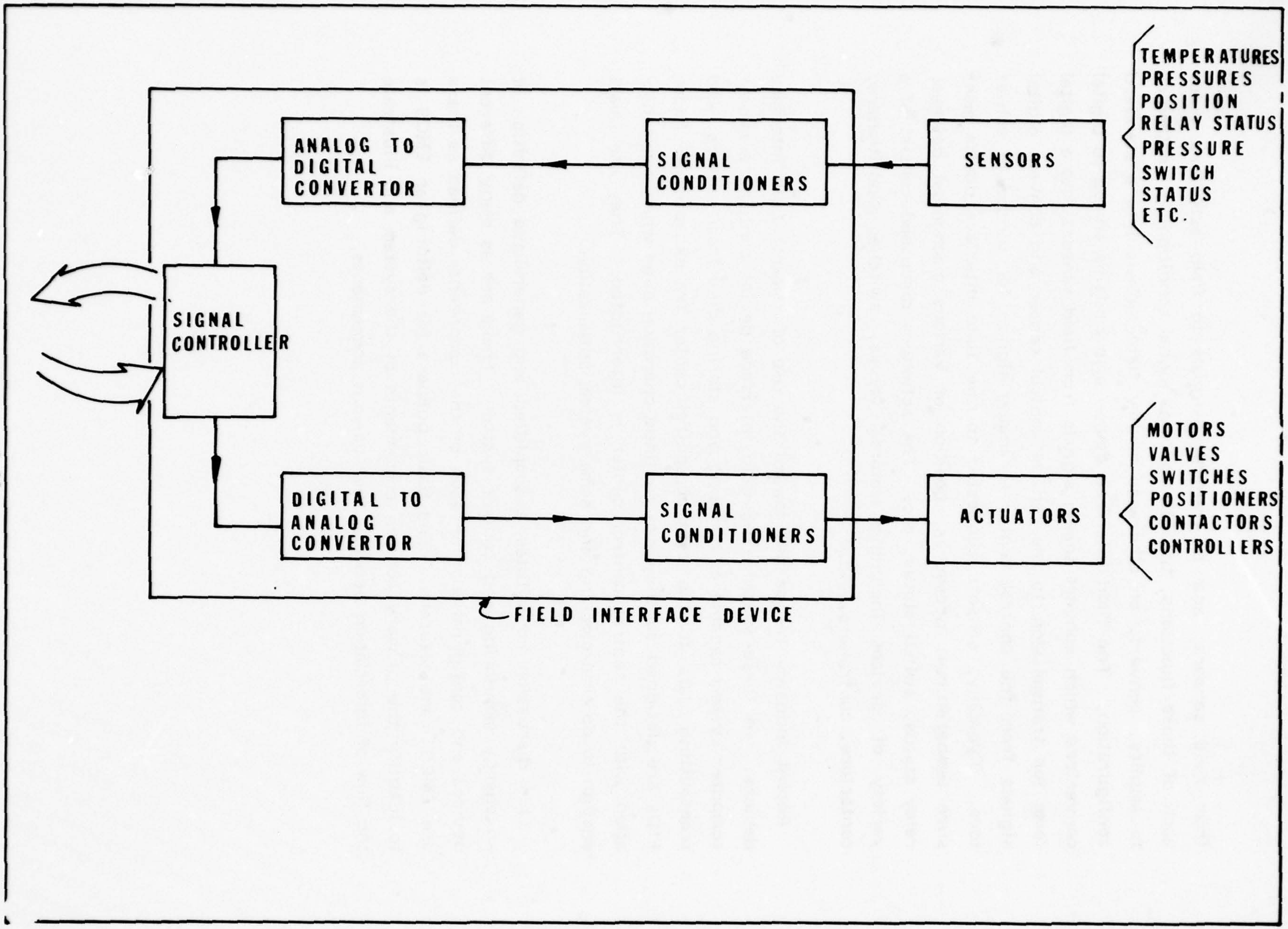


FIGURE 3 - EMCS REMOTE BUILDING CONFIGURATION

from field sensors, and to transmit signals to field actuators. For each of these functions, the FID contains signal conditioning electronics to amplify, convert, or otherwise modify field signals into a standard configuration. The field interface device also contains analog to digital convertors which convert analog signals from field sensors into a digital form for transmission to the central control center and convert digital signals from the control center to analog signals for control of actuators. Typically, sensors connected to the field interface device measure temperatures, pressures, position of various mechanical devices, relay status, switch status, etc. The actuators discussed consist of a variety of devices including motors, valves, switches, positioners, contactors, controllers, etc.

Recent industry trends are toward the use of "smart" field interface devices. In these systems the field interface device contains a microcomputer system capable of handling and storing data from sensors, and transmitting data to the central control center by exception. These FIDs are designed so they can continue operation even when communication with the central control center is interrupted. They are smart enough to do time clocking and some system optimization.

This discussion constitutes a simplified and generalized definition of an energy monitoring and control system. There are as many different devices and configurations for each of the components defined as there are EMCS manufacturers. The basic purpose for defining an EMCS is to identify the primary common components of the system and illustrate the flow of information between the various components.

1.4 EMCS LIFE CYCLE

To properly study EMCS applications it is necessary to consider the process by which an EMCS is created, used, and modified during its lifetime. This life cycle consists of seven stages. These are:

I. Determine what the EMCS is to do.

II. Prepare contract documents.

III. Award construction contract.

IV. Install.

V. Startup and checkout.

VI. Regular operation.

VII. Decision to expand system.

Steps I and II constitute the normal design process and are the areas with which this study is concerned. Once the decision to expand the EMCS (Step VII) is made, the process returns to Step I and the procedure is repeated.

Although the design process is important to the success of the EMCS life cycle, the other steps are equally important. The procurement methods used in Step III can determine whether or not successful bids are received. Decisions on whether to procure using Invitation for Bid (IFB) or Request for Technical Proposal (RFTP or Two Step) methods may affect the number of bidders interested in a project. Whether the EMCS project is classified as a Small Business Set-Aside or is open to direct bidding by all companies can have a substantial affect on prices.

The installation and startup and checkout processes are highly important to the EMCS life cycle. Even with perfect contract documents,

lack of adequate construction supervision and test monitoring can result in an installation of poor quality and marginal operation.

Finally the day to day operation of the EMCS has by far the greatest effect on its effectiveness as an energy conservation tool. If poorly trained or overburdened personnel are in charge of the system it can easily fall into a state of disrepair and lose the confidence of those using the system. Such a simple matter as the position of the EMCS operator within the Base Civil Engineering organization can limit the effectiveness of the energy saving aspects of the system.

In summary, this study addresses only a single portion of the EMCS life cycle. Although the design stage is an important part of the EMCS life cycle, all the other areas must be adequately considered and planned for in creating an effective EMCS program.

1.5 ANALYSIS CONCEPTS

The purpose of an Air Force EMCS is to reduce energy related costs through centralized control of energy consuming systems. Therefore, the objective of the design analysis of an EMCS is to determine the EMCS configuration which will produce the most savings for the least cost.

Before attempting to analyze an EMCS, two key concepts must be understood. Those are 1) what it is an EMCS performs and 2) what it is an EMCS performs its activities on.

What an EMCS does is called an EMCS "function". A function is defined as a specific independent operational capability. A function generally consists of several independent activities (data gathering and/or control commanding) linked together by logic to accomplish a specific purpose. Examples of EMCS functions are starting or stopping of equipment based on the time of day, enthalpy based control of an air handler economizer, or reset of a multizone air handler hot deck based on the zone with greatest heating demand. A single function may require the use of several sensors and/or actuators to perform its task. Conversely, it is true that a particular sensor or actuator may be used as a part of the performance of several different functions. A description of some of the more common EMCS functions is included in Section 1.6.

An EMCS performs its functions on "systems". A system, from an EMCS viewpoint, is defined as a group of energy consuming devices which operate together to perform a single common task. An example of a "system" is a water chiller with its associated chilled water pump, condenser water pump, cooling tower and various controls and interlocks all working together to perform a single task, to chill water. Individual items of equipment within a system do not operate independently of each other. From a control and analysis standpoint, each system will be considered to be independent of the operation of any other system. It is important to realize that an EMCS function must be applied to an entire system and not just to a particular item of equip-

ment within that system. If consideration is given only to the operation of a particular motor instead of to the system of which that motor is a part, installation and operational problems will occur from improper operation of local controls, motor interlocks, and other items with which the EMCS must interface in order to be effective. This makes effective energy reduction control difficult, and makes an objective engineering estimation of the savings resulting from that control impossible.

The concepts of EMCS "functions" and "systems" are central to the development of a logical analysis and contract document preparation approach. Before an EMCS is installed, the functions it is to perform, and the systems on which it is to perform those functions, must be thoroughly analyzed, investigated, and clearly specified.

With the function and system concepts in mind, the EMCS design analysis process for a particular Air Force Base falls into three basic design problems. These are:

1. What systems are present?

2. Which EMCS functions are applicable to each system?

3. Which of the possible system/functions should be connected to the EMCS to provide the most savings for the least investment?

The first two items are relatively easy to solve. EMCS functions are discussed in Section 1.6, example systems are identified in Section 2 of this report, along with methodology relating the two. The third design problem is the most difficult.

After the system/functions (a "system/function" is a particular EMCS function applied to an individual energy consuming system) to be considered have been identified, each must be evaluated relative to all the other system/functions being considered. The evaluation criteria must

select the system/functions based on providing the most savings for the least investment. The criteria may be savings investment ratio, payback period, life cycle present worth, or any number of other economic approaches. In light of our current national energy situation, the criteria chosen could be in energy saved per dollar invested. The most widely used and easily recognized measure of the value of an alternative is the payback period. That criterion is used in this report, although other measures (S/I ratio, BTU/$ invested, etc.) can be used with no change in the basic approach or methodology contained herein.

The solution to the design problem (which of the possible system/functions should be connected to the EMCS) is very simple in concept. List all the system functions to be considered, estimate the potential savings resulting from each system/function, and estimate the cost to perform each system/function. With these values, a payback period can be calculated for each system/function. The system/functions can then be rearranged in ascending payback period order. Thus a "prioritized" list of system/functions can be prepared.

Once this prioritized list has been prepared, there are two alternative paths depending on the particular point at which the analysis is being performed. If the project is in the very early stages and a budget has not yet been established, the prioritized list may be used to determine what the project budget should be, depending on the governing criteria. If the criteria state that no part of the project should have more than a ten year payback period, then all system/functions with more than a ten year payback should be deleted from the list. The cost to provide the remaining system/ functions can then be totalled and that total establishes the budget level.

If, on the other hand, the design analysis is being performed after a budget limit has been established, the prioritized list can be used to determine the EMCS configuration which will provide the greatest savings for the budget investment. In this case, starting at the top of the list, a cumulative total of the system/function cost is run until that total reaches the budget amount. At that point, the system/ functions

not yet added to the total are deleted from the list. The system/functions remaining on the list are those that will provide the most savings for the least investment, thus producing an optimized EMCS configuration.

This approach is theoretically simple and satisfies the design objective. The most obvious disadvantage of this approach is the large number of calculations necessary to estimate the potential savings and cost for each system/function. This disadvantage can be overcome by a systematic, uniform approach to the analysis of each type of system. Examples of the approach used in the EMCS analysis of Fairchild, Homestead, and Grand Forks AFB's are included in Section 2 of this report.

Unfortunately, two factors complicate the procedure described above. These are:

1. EMCS field hardware duplicity

2. EMCS geography cost

The term "field hardware duplicity" refers to the fact that a particular EMCS field hardware device (temperature sensor, start/stop control relay, etc.) may be used in the performance of more than one function on a particular system. For example, the same start/stop control interface can perform both demand limit load shedding and time scheduled operation functions on an air handling unit. Therefore, if a start/stop control interface is provided because the time scheduled operation function has a very good payback period, the demand limit load shedding function can be performed on that air handler at no additional cost. Assume the optimized start/stop function for this air handler requires both a start/stop control interface and a space temperature sensor. On its own merits, optimized start/stop may not provide enough savings to justify purchasing both the control interface and temperature sensor. However, if the control interface is justified and paid for based on the time scheduled operation and demand limit

load shedding functions, the only cost to add optimized start/stop for this air handler is that of the temperature sensor, thus the payback period for this function is substantially improved. The cost sharing aspects of the field hardware duplicity concept become more complicated as the system being considered becomes more complex and the number of functions applicable to that system become larger.

The second complicating factor "EMCS geography cost" is similar to field hardware duplicity in that it is caused by the cost sharing aspects of EMCS hardware. The term "geography cost" refers to the fact that there is a more or less fixed cost involved in connecting a building to the EMCS. Geography cost includes all costs not directly related to the performance of a particular function on a specific system within a building. These costs include the cost of the transmission system from the building being considered to the point at which it will connect to the EMCS and the cost of the first field interface device (with its associated power supply and other required equipment) within that building. The geography cost is the fixed cost necessary if only one function for one system within that building is to be connected to the EMCS.

Each of the two complicating factors discussed can have a substantial impact on the simple prioritization of system/functions discussed previously. If the field hardware duplicity factor is not taken into account, functions which actually may be obtained with little or no expenditure may not be included in the final EMCS configuration produced by the analysis. If the geography costs of an EMCS are not properly accounted for, a building with a single system might be connected to the EMCS while another building with ten systems (each of which has slightly less savings potential than the single system in the other building) might not be included in the final EMCS configuration.

To solve these problems, the scope of their influence must first be defined. Field hardware duplicity is a variable only within each individual system. Because a system is defined as an independent operational unit from a control viewpoint, devices provided for one system

are not used in the performance of functions on another system. There are exceptions to this rule, but not enough to affect the analysis results substantially. So the field hardware duplicity factor may be accounted for by analyzing all the functions applicable to a particular system as a group.

The scope of influence of geography cost is confined to the building level. Geography cost varies strictly on a building by building basis, regardless of what systems or functions are within those buildings. Geography cost is present, independent of what type of data transmission media or field interface device is used. So geography cost must be considered in the analysis only when deciding whether or not to connect a building to the EMCS.

The method used to account for field hardware duplicity is to perform a repetitive ranking process on the functions applicable to each system. First, all functions applicable to a particular system are listed. Savings resulting from the application of each function are estimated. The cost to apply each function is estimated. This is done for each function, assuming no other functions are under consideration. A system schematic which illustrates what sensors are required to perform each function is needed to accomplish this cost estimate. Examples of such schematics are included in Section 2 of this report. Using the cost and savings figures estimated, a payback period is calculated for each function. The function with the best payback period is assigned the highest rank. When a function has been ranked, that function is assumed to be connected to the EMCS. A revised cost is then calculated for the remaining unranked functions on the basis that the ranked functions (and their associated field devices) are already connected to the EMCS. Thus, any sensors or controllers that are common between the ranked function and the remaining function have already been paid for. Their cost may be deducted from the independent cost estimates for each remaining function to obtain a revised cost. The revised costs are used to calculate new payback periods for each remaining function. The function with the best payback period of the remaining group is established as the function with the next highest rank. The iterative

process described above is continued until all functions applied to a particular system have been ranked, based on their payback periods, and their costs have been revised to account for the previous connection of functions with higher rank. The function ranking procedure is repeated for each individual system considered for connection to the EMCS.

One result of the ranking process is that after a function is ranked and the cost of the remaining functions is revised, the payback period for some of the unranked functions could be better than for some of the ranked functions. The extreme example of this situation is when two functions require exactly the same field devices. The ranking process would independently analyze each function and then select the one with the highest savings (since each would have the same calculated cost) to be ranked first. The process would then revise the cost estimate of the remaining function, taking into consideration the previously ranked function. This will result in a zero cost for the remaining unranked function. Thus, the ranking would actually show a function having the highest rank with a lower payback period than the next lower ranked function. If these functions are combined, the resulting combined payback period would be better than the payback period of the higher ranked function by itself. Therefore, following the ranking of functions for each system, a combination process must be performed on the ranked functions for each system. This is a simple process of examining each ranked function and, if the next lower ranked function has a better payback period, combining it with the next lower ranked function.

Geography cost is accounted for in the final prioritization process. Because geography cost is relevant only on a building by building basis, the system/function prioritization process must also be organized along those lines. The system/functions being considered for EMCS connection must be grouped based on the building in which they occur. For each building, these system/functions are sorted, based on a payback period, into a table for use in the prioritization analysis. Once the tables are prepared for each building, the geography cost to con-

nect each building must be estimated. This cost includes all items not directly associated with the performance of a particular function (FID, power supply, transmission cable, etc.) and is calculated assuming no other buildings are being considered. The geography cost for each building is then combined with the tabulated system/functions for that building until the best combination (from a payback period standpoint) of system/functions is found for each building. The building with the best combined payback period is then selected to be the first building connected to the EMCS. The best system/function in that building is placed on the top of the prioritized system/function listing. Because parts of the transmission network may be common to several buildings (in the case of contractor furnished transmission cable), the geography cost for each building must be recalculated after each building is connected. The revised geography cost is then used to recalculate a best combined payback period for each building not yet connected to the EMCS. These revised building payback periods are then compared to each other and to the best individual system/functions in buildings already connected to determine the next system/function to be added to the prioritized list. This process is repeated until all system/functions in all buildings have been placed on the prioritized list.

Once the prioritized list is completed, it may be used as described earlier to establish the proper EMCS budget or to determine the best configuration for a given budget.

It can readily be seen that the effort required to account for the "field hardware duplicity" and "geography cost" factors can be substantial. The approach is simple in concept, however, the repetitive calculations required are extremely time consuming. To alleviate this problem, a series of computer programs have been developed. These programs perform both the "field hardware duplicity" and "geography cost" analysis described above. In addition, programs are included to provide listings and summaries of pertinent information. These report generation programs produce exact counts of the numbers of each type of sensor and the quantitites of savings (KW, KWH, THERMS, MH).

The programs are constructed around the concept of standard system types as illustrated on schematics in Section 2 of this report. No fixed system configurations are contained within the programs. The EMCS designer must construct his own system schematics and prepare input data describing those system types. This allows flexibility in the use of the analysis technique regardless of individual design philosophies. The input for standard system types includes the functions applicable to each system, what field devices are necessary to perform each function, what type of instrument each of those devices is, what each type of instrument costs, and alpha-numeric description of each item for interpretation and checking of results. Once an input data file for a set of standard system types has been constructed, it may be reused for the analysis of as many different projects as desired, as long as the same design philosophy is being used.

Additional input data consist of calculated savings values for each applicable function for each system being considered for EMCS connection. These values are entered in KW (electrical demand reduction), KWH (electrical consumption reduction), THERMS (heating energy consumption reduction), and MANHOURS (labor savings). Other input includes a nodal network describing the "geography" of the EMCS configuration being considered.

The use of the computerized analysis tools is not mandatory for the use of the analysis technique described in this report. Step by step instructions in the manual use of the technique are included in Section 3 of this report. However, substantial engineering time savings may be realized from the use of the computer programs which are documented in Volume II of this report.

1.6 FUNCTION IDENTIFICATION

As stated previously, an EMCS function is defined as a specific independent operational capability. An EMCS can perform many different functions. It can be programmed to monitor, regulate, and control almost an infinite number of tasks. The same tasks may also be accomplished in an infinite number of ways. The identification used for a particular function varies with the individual EMCS manufacturers and their methods and approach to a particular function may also vary. This variation generally depends on the particular software or hardware a manufacturer uses to accomplish each function, rather than the function itself. Therefore, it is possible to identify individual functions the EMCS can perform. The following paragraphs identify the EMCS functions considered in this study. These represent the most common functions available from EMCS manufacturers today. Additional functions exist and may provide some additional energy and manpower savings, however, those listed will most certainly provide the bulk of these savings.

The following paragraphs describe each function considered in this study.

FUNCTION NO. 1: TIME SCHEDULED OPERATION

Time scheduled operation consists of the starting and stopping of a system based on the time and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. This is the simplest of all EMCS functions to install, maintain, and operate. It also provides the greatest potential for energy conservation if systems are currently being operated unnecessarily during unoccupied hours.

FUNCTION NO. 2: DUTY CYCLING

Duty cycling consists of the shutdown of a system for predetermined short periods of time during normal operating hours. This function is

normally only applicable to heating, ventilating, and air conditioning systems. Its operation is based on the theory that HVAC systems seldom operate at peak output, thus if the system is shut off for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during this shutdown. Although the interruption does not reduce the net space heating or cooling energy, it does reduce energy input to constant auxiliary loads such as fans and pumps. This function also reduces outside air heating and cooling loads since the outside air intake damper is closed while an air handling unit is off. Systems are generally cycled off for some fixed period of time, say 15 minutes, out of each hour of operation. The off period time length and its frequency should be adjustable. The off period time length is normally adjusted for a longer duration during moderate seasons and shorter duration during peak seasons.

FUNCTION NO. 3: DEMAND LIMITING START/STOP

This function consists of the stopping of electrical loads to prevent setting a high electrical demand peak and thus increasing electrical costs where demand oriented rate schedules apply. There are many complex schemes for accomplishing this function. They all generally monitor the base electrical demand continuously. Based on the monitored data, demand predictions are made by the EMCS. When these predictions exceed preset limits, certain scheduled electrical loads are shut off by the EMCS to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the function requirements. Generally, the loads to be shed are HVAC items. The reasoning used in the Duty Cycling discussion holds here also: allow a slight temperature drift in the space by shutting off the HVAC equipment.

FUNCTION NO. 4: DEMAND LIMITING, GENERATOR OPERATION

This function is actually a part of the program that controls the DEMAND LIMITING, START/STOP function. In fact, the only difference

between the two functions is that the previous function stopped equipment to reduce demand and this function starts equipment for the same purpose. This function is only applicable where large standby generators are existing. When electrical demand approaches a peak, this function starts the engine or turbine generators which feed electrical power into the building where they are located, or drive specific items of equipment such as well water pumps, thus reducing base electrical demand. Extreme caution must be exercised in using this function. Only the largest of generators should be considered because considerable investigation and expense may be necessary to perform any rewiring or reswitching needed for proper operation of this function.

FUNCTION NO. 5: DEMAND LIMITING, CHILLER LIMIT ADJUST

Centrifugal water chillers are generally equipped with a manually adjustable control system which limits the maximum current, and thus power, the machine may use. An interface between the EMCS and this control circuit allows the EMCS to reduce the limit setting in a load shedding situation and thus reduce the electric demand without completely shutting down the chiller. The method of accomplishing this function varies with the specific manufacturer of both the water chiller and the EMCS. The principle of operation is the same, however. When the chiller is selected for load shedding, a single stop signal is transmitted to the interface which then reduces the chiller limit adjustment by a fixed amount. Normally, the actual setting of the chiller limit adjust is not resettable or even detectable from the EMCS. Extreme caution must be exercised with application of this function. Incorrect interface and control can cause the refrigeration machine to operate in a surge condition, ultimately causing considerable damage to the equipment.

FUNCTION NO. 7: WARM UP/NIGHT CYCLE

The thermal load imposed by outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements for a facility, depending on the geographical location. This

function is capable of controlling the outside air dampers when the introduction of outside air would impose a thermal load and the building is unoccupied. This function would apply during warm up or cool down cycles prior to occupancy of the building and would also apply in certain facilities that require maintenance of environmental conditions for proper operation of electronic equipment, even though the building is unoccupied. During those times, the outside air dampers would be closed.

FUNCTION NO. 8: ENTHALPY ECONOMIZER

The utilization of an all outside air economizer cycle can be a cost effective energy conservation measure, depending on the climatic conditions and the type of mechanical system. Where applicable, the cycle uses outside air to satisfy all or a portion of the building's cooling requirements when the enthalpy or total heat content of the outside air is less than that of the return air from the space. Outside air is introduced through the mechanical system and relieved during this cycle in lieu of the normal recirculation system.

FUNCTION NO. 9: SPACE TEMPERATURE NIGHT SETBACK

The energy required to maintain space conditions during the unoccupied hours can be reduced by lowering the temperature set point for the space, depending on the climatic conditions. This function would also apply only to facilities that are not required to operate 24 hours per day. Normally, where applicable, this function would reduce the space temperature from the normal 68° winter inside design temperature to a 50° or 55° space temperature during the unoccupied hours.

FUNCTION NO. 10: HOT/COLD DECK TEMPERATURE RESET

Mechanical systems such as dual duct systems and some multizone systems use a parallel arrangement of heating and cooling surfaces commonly referred to as hot and cold deck surfaces for the purposes of providing heating and cooling mediums simultaneously. Generally speak-

ing, both heated and cooled air streams are mixed to satisfy the individual space thermal requirements. In the absence of optimization controls, these systems can waste energy because the final space control merely mixes the two air streams to produce the desired result. While the space conditions may be acceptable, the greater the difference between the temperatures of the two streams, the more inefficiently the system will operate. This function can select the individual areas with the greatest heating and cooling requirements, establish the necessary hot deck and cold deck temperatures based on these extremes, and minimize the inefficiency of the system.

FUNCTION NO. 11: REHEAT COIL TEMPERATURE RESET

A variation of the hot and cold deck multizone system described above is the system equipped with a cold deck and a bypass section at the mechanical system and individual heating coils in the reheat position downstream from the unit. The system operates with a constant cold deck temperature which is, in turn, mixed with the bypass air in an effort to satisfy individual zone requirements. Air supplied at temperatures below the individual space temperature requirements is elevated in temperature by the reheat coil in response to signals from an individual space thermostat. Selection of the space with the greatest cooling requirements and resetting the cold deck discharge temperature in response to these requirements minimizes the energy used for reheat.

FUNCTION NO. 12: CHILLED WATER RESET

The energy required to generate chilled water in a reciprocating or centrifugal electric driven refrigeration machine is a function of a number of parameters including the temperature of the chilled water leaving the machine. Because the refrigerant suction temperature is a direct function of the leaving water temperature, the higher the two temperatures, the lower the energy input per ton of refrigeration. As a result, because chilled water temperatures are selected for peak design times, in the absence of strict humidity control requirements,

most chilled water temperatures can be elevated during most operating hours. Depending on the operating hours, size of the equipment, and configuration of the system, energy savings can be effected by resetting the chilled water. The chilled water temperature can be elevated to satisfy the greatest cooling requirements. Generally, this determination is made by the position of the chilled water valves on the various cooling systems. The positions of the control devices supplying the various cooling coils are monitored and the chilled water temperature is elevated until at least one control device is in the maximum position. Other control schemes may be necessary to satisfy different system configurations.

FUNCTION NO. 13: CONDENSER WATER TEMPERATURE RESET

Another parameter affecting the energy input to a refrigeration system is the temperature of the condenser water entering the machine. Conventionally, heat rejection equipment is designed to produce a specified condenser water temperature such as 85° at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain a specified temperature at conditions other than peak design. To optimize the performance of the condenser water system, however, this system can be reset when outdoor wet bulb temperatures will produce lower condenser water temperature. Where applicable, this function will reduce the energy input to the refrigeration machine.

FUNCTION NO. 14: OUTSIDE AIR TEMPERATURE RESET SCHEDULE

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are designed to supply the heating requirements for the system at outdoor design temperatures. Frequently, depending on the specific system design, the hot water supply temperature can be reduced as the heating requirements for the facility are reduced. For most facilities, this reduction in heating requirements is directly related to an increase in outdoor ambient temperature. Where applicable, the capability to reduce the temperature of the supply water as a function of outdoor temperature will effect operating savings. To accomplish

this function, the temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature.

FUNCTION NO. 16: START/STOP OPTIMIZATION

An additional feature of the time scheduled operation of mechanical systems described above is the optimized start/stop feature available from the system. Mechanical systems serving areas that are not occupied 24 hours a day should be shut down during the unoccupied hours. Traditionally, the systems are restarted before occupancy in order to cool down or heat up the space. Normally this function is performed on a fixed schedule independent of weather, space conditions, etc. The optimized start/stop feature of the system automatically starts and stops the system to minimize the energy required to provide the desired environmental conditions during occupied hours. The function automatically evaluates the thermal inertia of the structure, the capacity of the system to either increase or reduce temperatures in the facility, start-up and shut-down times, and weather conditions to accurately determine the minimum hours of operation of the HVAC system to satisfy the thermal requirements of the building.

FUNCTION NO. 17: BOILER PROFILE AND SELECT

In certain application of multi-boiler central heating plants, there is the opportunity to optimize the boiler plant by selecting the most efficient equipment to satisfy the instantaneous heating requirement. By monitoring fuel input as a function of the output, profiles can be developed for each of the units in a central plant. Based on the operating history developed, and the loads, plant operation can be optimized to minimize energy input.

FUNCTION NO. 18: CHILLER PROFILE AND SELECT

This function is very similar to the boiler profile described above. Operating data are obtained and compared with the predicted operating characteristics of each individual machine prepared by the manufac-

turer. Based on the operating data for each machine with the energy input requirements for each operating condition and the instantaneous load, the function would select the chiller or chillers required to meet the load with the minimum energy input.

FUNCTION NO. 19: PUMP SELECTION:

The opportunity exists in certain chilled and hot water central pumping systems to optimize the selection of the number and type of pumps to minimize the energy input for pumping cost. This condition would exist when fixed speed pumps of varying capacities are provided or a combination of fixed speed and variable speed pumps is provided to satisfy a central secondary water pumping system.

FUNCTION NO. 21: SECURITY FUNCTION:

A considerable number of security features can be provided by the system including contact alarms for monitoring of controlled entrance and exits, motion detectors, card readers, watchman tours, etc. Practically any security function can be monitored by the system if an indication of its condition can be converted to an acceptable signal.

FUNCTION NO. 22: FIRE ALARM FUNCTION:

The system can operate as an integral part of the individual facility fire alarm system receiving and diagnosing signals with commands issued or can function merely as a monitoring system of the individual building fire alarm systems. As an integral part of the total fire alarm system, all the components must be UL listed and the installation must comply with NFPA 72D requirements. These requirements include the necessity for complete backup power system, double transmission of signals, backup central processing equipment, etc. The requirements to monitor the existing individual systems are less strict because the monitoring is taking place only to provide information. Because most facilities on military installations are equipped with existing independent alarm systems, it appears logical to allow these systems to continue to operate independently and monitor the operation of the system where feasible.

FUNCTION NO. 23: MAINTENANCE RUN TIME REPORTS:

A number of maintenance functions associated with mechanical equipment are related to or can be related to the number of operating hours of the specific item of equipment. Some of these functions include lubrication, cleaning, bearing checks, etc.

FUNCTION NO. 24: TROUBLE DIAGNOSIS:

By monitoring certain parameters of the mechanical/electrical systems, diagnoses of reported problems with mechanical and electrical systems can be performed at the central console location. Some of the parameters that might be monitored for the purposes of trouble diagnoses include hot and cold deck temperatures with high and low limits, leaving chilled water temperatures and hot water temperatures with high and low limits, differential pressure switches indicating fan and pump operation, and space temperatures.

FUNCTION NO. 25: CRITICAL AREAS ALARM:

Areas such as electronic data processing equipment rooms, test facilities, environmental test rooms, and other areas with critical requirements for environmental control can be monitored for status and alarm indication.

FUNCTION NO. 26: SAFETY ALARMS:

Many items of mechanical equipment are provided with various types of alarms for both personnel and equipment protection. Alarms such as high and low water for boilers, gas pressure alarms, and various temperature and pressure alarms on refrigeration machines, are typical of the types of functions that can be monitored. Monitoring of such alarms provides the console operator with information regarding the failure of equipment or the development of potential problems with the system operation.

FUNCTION NO. 27: INTERCOM:

A function of the system that can be beneficial from a maintenance standpoint is the capability of communicating between the operator's console, the field interface devices or other remote intercom station locations. The system can be used for intercommunication between maintenance personnel and console operator for a check out of the overall system, and for monitoring of start up of equipment.

1.7 COST IDENTIFICATION

The accurate analysis of an EMCS requires accurate and reliable cost estimating data. This is extremely important because potential savings alone do not determine whether a particular function should be connected to the EMCS. The cost of that function is equally important in determining whether or not it should be connected. Cost estimating is of additional importance because cost for a particular EMCS function is relatively constant, irrespective of the size of the system being controlled. It essentially costs the same to start and stop a ten horsepower fan as it does to start and stop a one horsepower fan. However, the difference in potential energy savings is tenfold.

Several items complicate the cost estimating analysis. The first and probably most important complication is the fact that no two manufacturers' EMC systems are identical. Every manufacturer takes a different approach to performing each EMCS function. For example, because of a particular configuration, one manufacturer may be able to provide a status feedback for a piece of equipment being started and stopped by the EMCS for a very small cost, whereas a different manufacturer with a different configuration might actually double the cost of simply providing start-stop capability, if status feedback is required. Another difficulty arises from the reliability of budget estimates received from manufacturers' sales representatives. For obvious reasons, these representatives generally are very guarded about revealing detailed or exact cost information. They generally prefer only to give rough budget estimates based on the total number of points in a system. This type of information is not adequate for the detailed analysis techniques developed under this project. Each component cost of the EMC system must be broken down separately to perform the comparative analysis necessary for an optimized EMCS. Obtaining this type of information has been difficult. However, several manufacturers were willing to provide the information which has been used in this study.

In order to determine an optimum EMCS configuration, each cost component of the system must be analyzed. The five main cost com-

ponents of an EMCS are 1) general cost, 2) central control center cost, 3) transmission system cost, 4) facility connection cost, 5) sensor/actuator cost.

General cost consists of the following components:

a. Estimation
b. System engineering
c. Shop drawing preparation
d. System testing and debugging
e. Training
f. Maintenance contract

All of these costs involve a considerable amount of overhead time, thus making them only slightly dependent on the number of facilities and sensor/ actuators connected to the EMCS.

The central control center cost consists of the following main components:

a. Central processing unit hardware
b. Peripheral hardware and associated software drivers
c. Operating system software
d. EMCS command software
e. EMCS applications software
f. Multiplexer hardware
g. Communications software

The cost of these components is relatively constant, regardless of the number of facilities or sensor/actuators that are connected to the system.

The transmission system cost consists of:

a. Overhead transmission cable
b. Underground transmission cable
c. Telephone modems (Modulator-demodulator)

This cost is basically a function of the number and location of facilities connected to the EMCS.

Facility connection costs are those fixed costs associated with connecting a facility to the EMCS which are independent of the number of sensors/actuators that are installed within that facility. Facility connection cost is the fixed cost which would be incurred to connect a facility to the EMCS even though that facility only required a single EMCS sensor. The components of facility connection costs are:

a. A field interface device, along with its power supply and installation

b. The transmission line to the building in question, if a dedicated contractor installed transmission system is being utilized

c. Telephone lines and modems from the building in question back to central console location if a telephone transmission system is used

The facility connection costs listed above are strictly dependent on the number of facilities connected to the EMCS and not on the number of sensor/ actuators.

The sensor/actuator cost is the cost to add a sensor/actuator to the EMCS, assuming a field interface device to which this point will be connected is already available in the building. Cost components associated with each sensor/actuator are:

a. A signal conditioning device usually in the form of an integrated circuit card which plugs into an appropriate slot in the field interface device

b. Wiring from the field interface device to the sensor/actuator

c. The sensor/actuator itself

d. The installation and interface of the sensor/actuator with the existing local control system

e. Local controls which must be replaced, repaired, or added

f. Miscellaneous new equipment (dampers, ductwork, thermometer wells, Venturi tubes, insulation, auxiliary starter contacts, etc.)

g. Definition and entry of each sensor/controller into the central control center

The total sensor/actuator cost is a function of the number of points connected to the EMCS and generally not related to the number of different facilities in which those points occur.

Several manufacturers were contacted and presented with a list of questions designed to obtain specific cost estimates for the components listed above. The data supplied as a result of this request are listed in Table I. Spaces left blank indicate that information was not supplied for that item by that manufacturer. Some manufacturers requested that their prices not be openly presented for protection from their competition; therefore, none of the manufacturer's names have been listed. It should be pointed out that both conventional controls manufacturers and the smaller "systems house" manufacturers are included in those listed. Prices were updated twice during the course of this study. The final figures included here were obtained during January, 1978.

TABLE 1
COST ESTIMATING DATA
MANUFACTURERS

	A	B	C	D	E	F	G	H	I	VALUE USED IN STUDY
A. General										
1. Training	3500			4100			4000	720	3600	3800
B. Field Equipment										
1. Field Interface Device (FID)	2000	1750	8000	3000	4700	7500	3500	3000	3000	3100 w/o Modem
2. Multiplexer Panels (MUX)	800						1200	1200		1200
3. a. Intercom	250	225	650	620	225					300
b. Temperature	250	250	500	520	240	250				300
c. Pressure	350	470	500	1220	500	600				500
d. Relative Humidity	250	545	500	1220	480					500
e. Contact Status	250	150	400	320	240	150				250
f. KW	1000	1250	1450	1220						1250
g. Reset Temp Controller	650	510	600	760	420					650
h. Reset Damper Position	650	375		570	420	600				570
i. Reset S/W Changeover	450	250	400	470	420					450

TABLE 1
COST ESTIMATING DATA
MANUFACTURERS

	A	B	C	D	E	F	G	H	I	VALUE USED IN STUDY
j. Motor S/S w/Status	450	250	400	470	320					450
k. Flow Measurement			2300	3220		600				2300
l. Chiller Limit Adjust				1220						1220
m. Zone Demand Selection										450
n. Diff. Pres. Status										300
C. System Equipment										
1. Central Communications Controller (CCC)	25000	2000		600	In C.2	5000	2000	11000	9600	12000
2. Central Control Unit (includes Maintenance and Control Panel, Real Time Clock)	37000	20000		In C.1	52700	20000	20000	48000	33000	40000
3. External Uninterruptible Clock		800		2500			800			800
4. Disk Memory Units	17000	14000		In C.1	30000	15000	14000	25000	5200	22000
5. Alarm and Logging Printer	2500			In C.1	4000	3000	2500	2000	2380	2500

TABLE 1
COST ESTIMATING DATA
MANUFACTURERS

		A	B	C	D	E	F	G	H	I	VALUE USED IN STUDY
6.	Report Printer	4500	10000			6000	7000	5500	4000		6000
7.	CRT: Semi-Graphic, 8-Color	5000			In C.1	In C.1			12000	8000	7000
8.	CRT: Black and White	2500					3000	2500	3000	2450	3000
9.	Paper Tape Reader/Punch	4000					3000	3500			2500
10.	Intercom, Master	In C.1			In C.1	In C.1		1200	3500	300	2000
D.	Software										
1.	Command				10000	30000	In D.2	In D.2			20000
2.	Applications						30000 (Total)	30000 (Total)			
a.	Time Control Program	2500			Base System	Base System					1500
b.	Demand Limiting	Duty Clc.	12000		3600	3600					3700
c.	Duty Cycle Program	2500	20000		3600	1500					3000
d.	Optimized Start/Stop	1000	5000		5000	3700					4000
e.	Power Demand Statistics										

TABLE 1
COST ESTIMATING DATA
MANUFACTURERS

	A	B	C	D	E	F	G	H	I	VALUE USED IN STUDY
f. H/C Deck Reset	2500			Base System	3700					1000
g. Chiller Plant Optimization	2500			10000						5000
h. Elapsed Run Time	Base System			Base System	2200					1000
i. Enthalpy Control	5000			1500						2500
j. Maintenance Reports	1000			10000						2500
k. BTU Totalization	1000									1000
E. Signal Transmission										
1. Underground Cable, $/ft.	4.00	5.31		5.00	4.00		2.50			4.00
2. Aerial Cable $/ft.	2.05			5.00	4.00	1.00	2.50			4.00
3. Modem Pair	1500	1000		2000	2680	900				800
F. Full Maintenance Contract	$7/point per year + 1%/mo on Central Hardware			6% of Total Contract				6% of Total Contract		6% of Total Contract per Year

1.8 CONCLUSIONS AND RECOMMENDATIONS

The previous pages of this section and the other sections of this report contain the results of considerable investigation and effort. This work cannot be summarized briefly because the subject of this project, Air Force EMCS applications, is not a simple subject and thus a report on it is not a simple report. However, some simple conclusions may be drawn from this effort. These, and recommendations regarding them, are as follows:

1. The application of an EMCS to an Air Force Base will reduce energy consumption for that base.

2. The application of an EMCS to an Air Force Base will reduce energy related expenditures.

3. A methodology has been developed as a part of this study which determines the best EMCS configuration for an Air Force Base according to a given criterion.

4. The criterion on which an optimum EMCS is determined may be either energy savings or dollar savings. The two criteria are basically independent and a decision on which is to be used must be made prior to any EMCS analysis.

5. A thorough analysis should be performed on each proposed Air Force EMCS to determine the optimum configuration and whether or not that configuration is worthwhile on an energy saving or dollar saving basis.

2.0 SYSTEM SCHEMATICS AND ANALYSIS TECHNIQUES

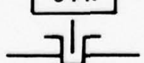
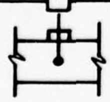
2.1 INTRODUCTION

The purpose of Section 2 of the AIR FORCE EMCS APPLICATION STUDY is to illustrate typical energy consuming systems and their relationship to an ENERGY MONITORING AND CONTROL SYSTEM (EMCS). This volume contains schematics of each type of system showing the devices required to perform each EMCS function on each system type. Analysis techniques for determining cost and savings for each EMCS system/function are included in Section 2.3. Survey and calculation forms for each typical system are included in Section 2.4.

The use of data contained in this section is directly related to specific analysis methodology described in Sections 1 and 3. The schematics and analysis techniques listed herein are included primarily for illustrative purposes. They represent one approach to EMCS applications. They are not necessarily the best approach and should not be considered the approach recommended by the Air Force. Each EMCS designer must rely on his experience to apply the many capabilities of an EMCS.

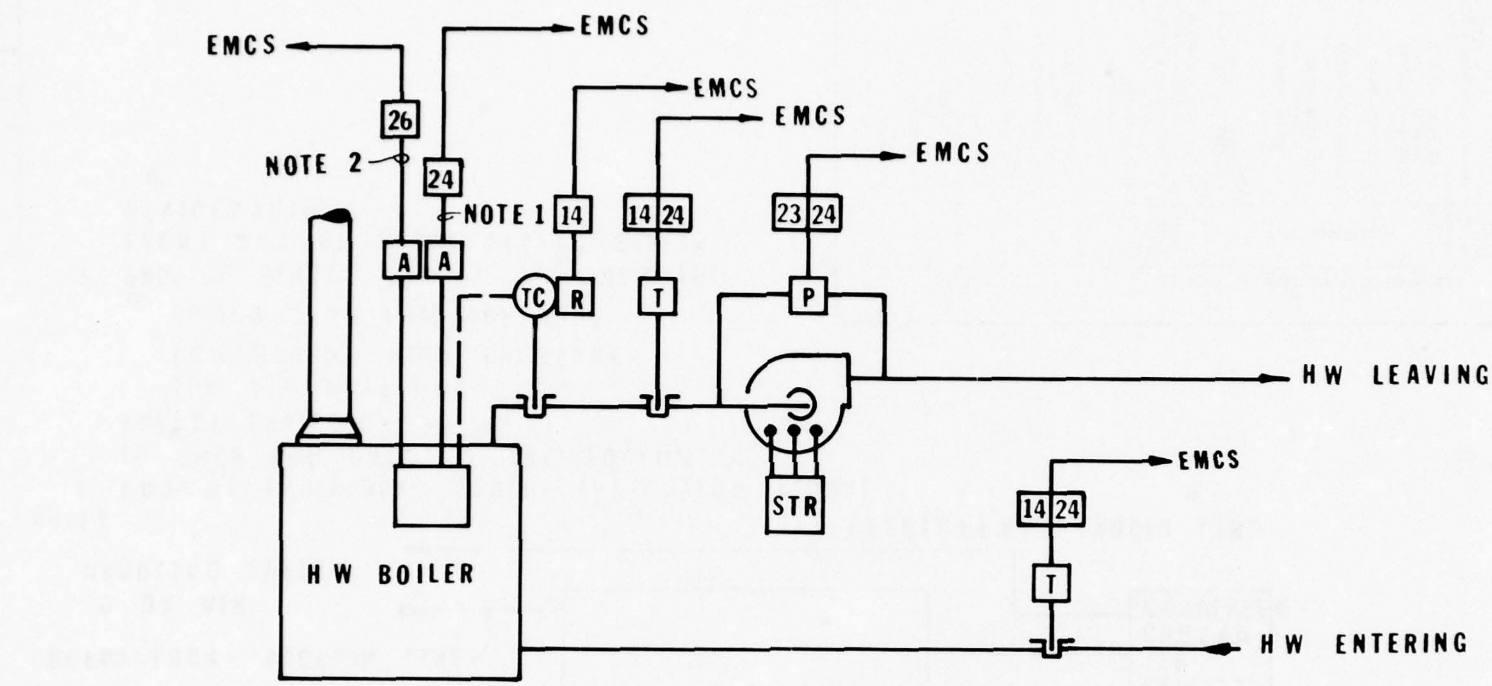
2.2 SYSTEM SCHEMATICS

SYMBOLS

→ EMCS	SIGNAL TRANSMITTED TO EMCS
← EMCS	SIGNAL RECEIVED FROM EMCS
$\boxed{A}$	ALARM CONTACT SIGNAL
$\boxed{C}$	GREATEST COOLING DEMAND SIGNAL
$\boxed{E}$	ENTHALPY ECONOMIZER CONTROL INTERFACE
$\boxed{H}$	GREATEST HEATING DEMAND SIGNAL
$\boxed{I}$	LOCAL CONTROL INTERRUPTION INTERFACE
$\boxed{L}$	PRESSURE INDICATION SIGNAL
$\boxed{O}$	ON/OFF STATUS SIGNAL
$\boxed{P}$	DIFFERENTIAL PRESSURE SWITCH STATUS SIGNAL
$\boxed{R}$	CONTROLLER RESET INTERFACE
$\boxed{S}$	START/STOP INTERFACE
$\boxed{T}$	TEMPERATURE INDICATION
$\boxed{W}$	HUMIDITY INDICATION SIGNAL
$\boxed{14}$	FUNCTION NUMBER WHICH REQUIRES SIGNAL
TC	TEMPERATURE CONTROLLER
PC	PRESSURE CONTROLLER
$\boxed{DS}$	HIGH/LOW DEMAND SIGNAL SELECTOR
$\boxed{STR}$	MOTOR STARTER
	SENSOR INSTALLED IN THERMOMETER WELL
	SENSOR INSTALLED IN DUCT OR PLENUM
CHW	CHILLED WATER

SYMBOLS CONTINUED

EA	EXHAUST AIR
EAD	EXHAUST AIR DAMPER
HW	HOT WATER
MA	MIXED AIR
MZD	MULTIZONE DAMPER
OA	OUTSIDE AIR
OAD	OUTSIDE AIR DAMPER
RA	RETURN AIR
RAD	RETURN AIR DAMPER
SA	SUPPLY AIR



NOTES:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF FOLLOWING SAFETY DEVICES.

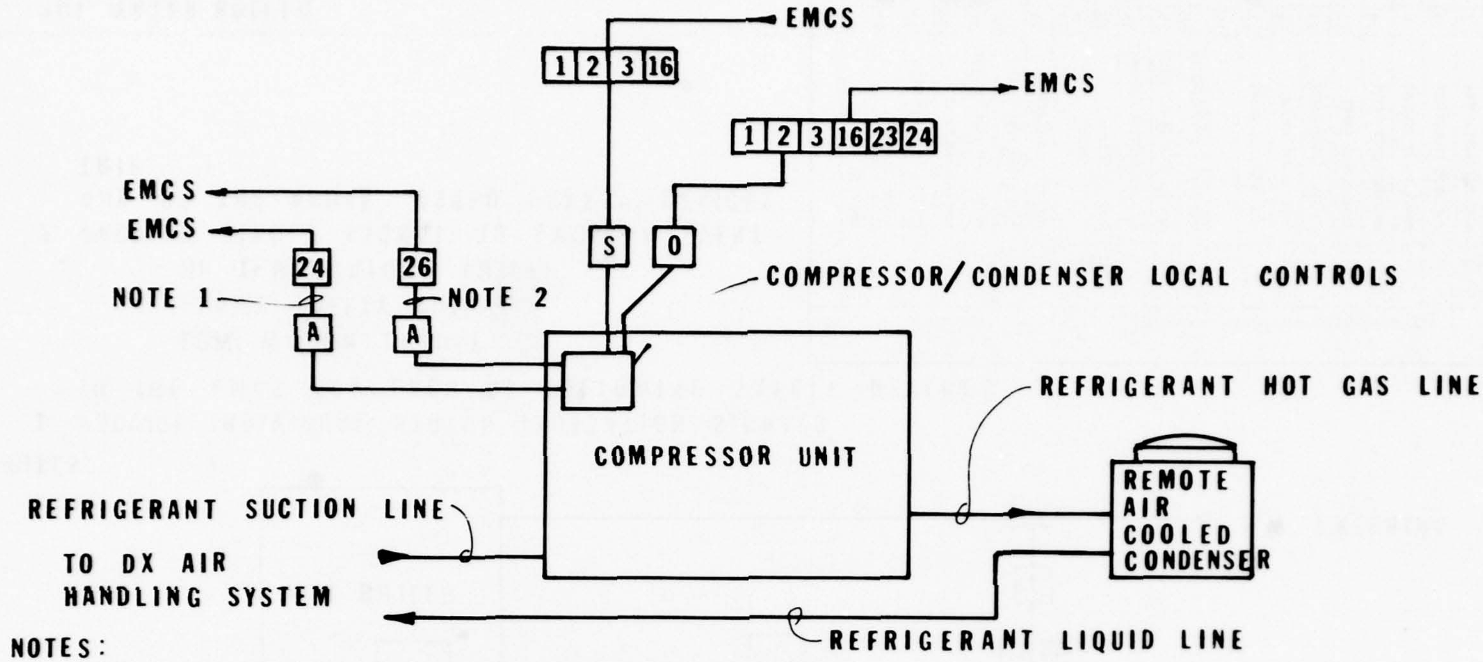
    LOW WATER CUTOFF
    FLAME SAFETY CUTOFF
    HI TEMPERATURE CUTOFF

2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF THE ABOVE LISTED SAFETY DEVICES TRIP.

			No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	●
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	●
		INTERCOM	27	
			28	

HOT WATER BOILER

SCHEMATIC S—1

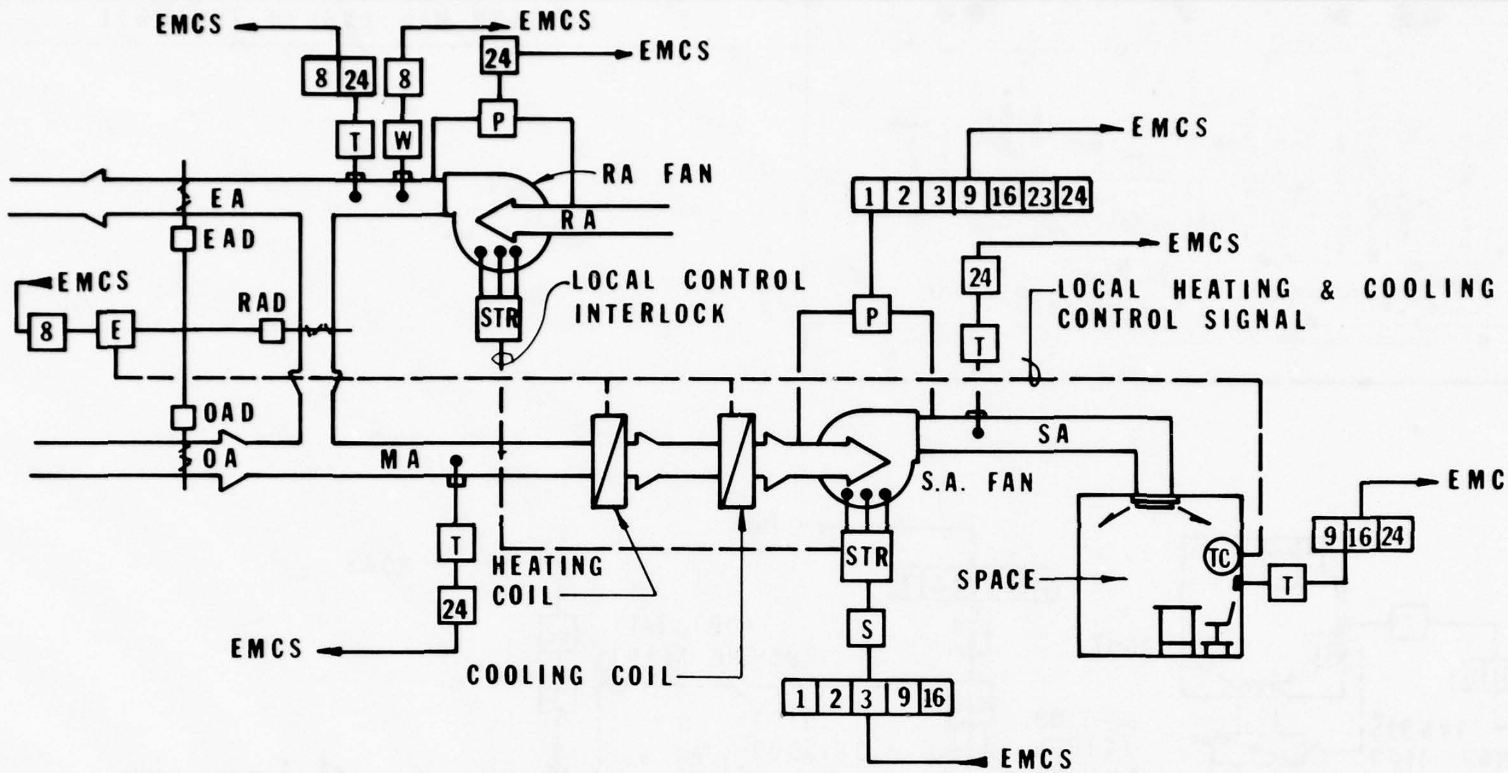


NOTES:
1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNAL TO EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES:
   LOW OIL PRESSURE
   COMPRESSOR HIGH PRESSURE
   COMPRESSOR LOW PRESSURE
2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIP.

EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	●
		INTERCOM	27	
			28	

DX UNIT, AIR COOLED

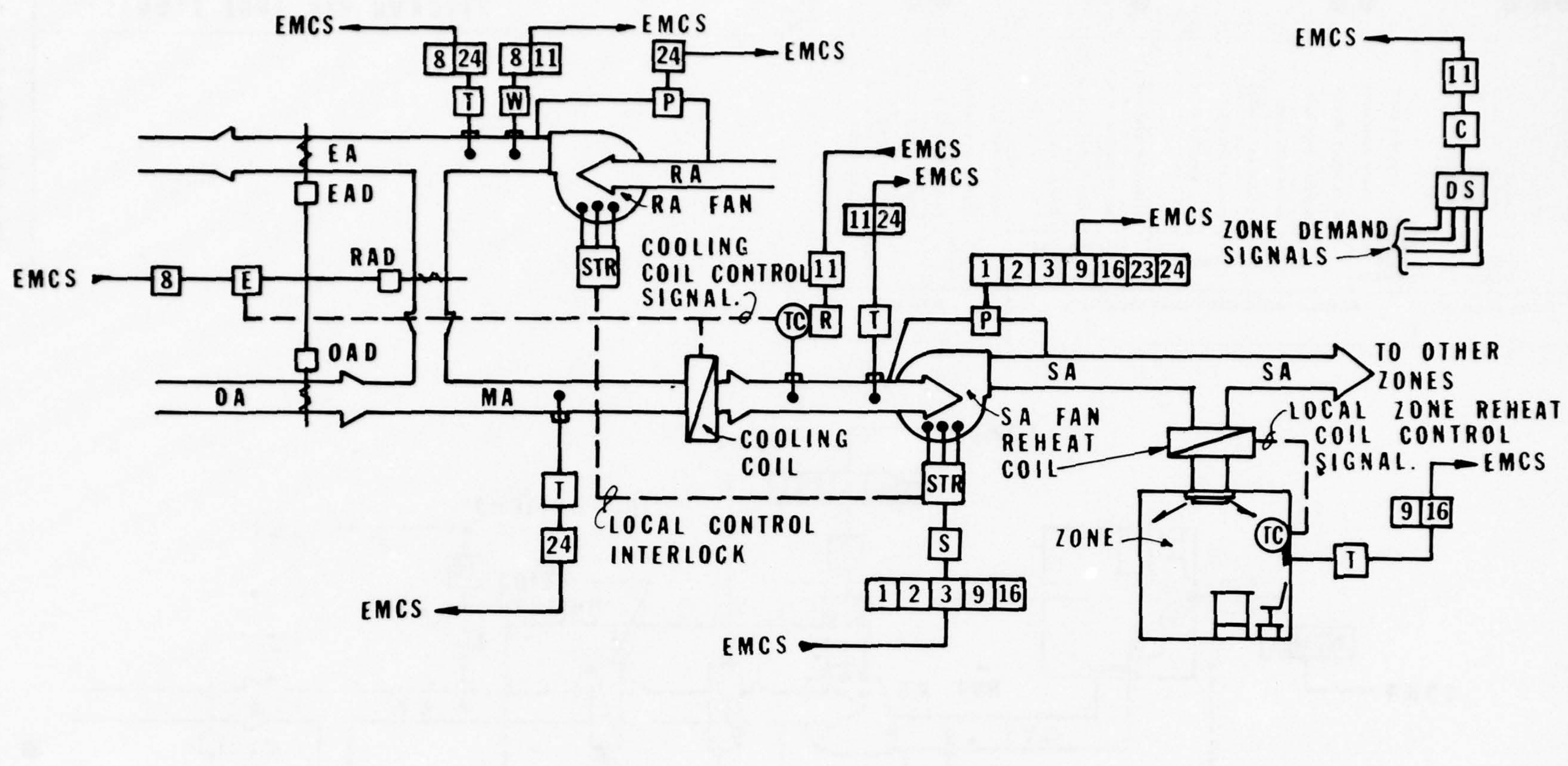
SCHEMATIC | S—2



No.	Category	Function	Selected
1	EQUIPMENT ON/OFF	TIME SCHEDULED OPERATION	●
2		DUTY CYCLING	●
3	DEMAND LIMITING	START/STOP	●
4		GENERATOR OPERATION	
5		CHILLER LIMIT ADJUST	
6			
7	EQUIPMENT OPTIMIZATION DURING OPERATION — OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	
8		ENTHALPY ECONOMIZER	●
9	TEMPERATURE RESET	SPACE NIGHT SETBACK	●
10		HOT/COLD DECK RESET	
11		REHEAT COIL RESET	
12		CHILLED WATER RESET	
13		COND. WATER RESET	
14		O.A. SCHEDULE RESET	
15			
16		START/STOP OPTIMIZATION	●
17	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	
18		CHILLER PROFILE & SELECT	
19		PUMP SELECTION	
20			
21	MONITORING	SECURITY FUNCTIONS	
22		FIRE ALARM FUNCTIONS	
23		MAINT. RUN TIME REPORTS	●
24		TROUBLE DIAGNOSIS	●
25		CRITICAL AREAS ALARMS	
26		SAFETY ALARMS	
27		INTERCOM	
28			

SINGLE ZONE AIR HANDLER

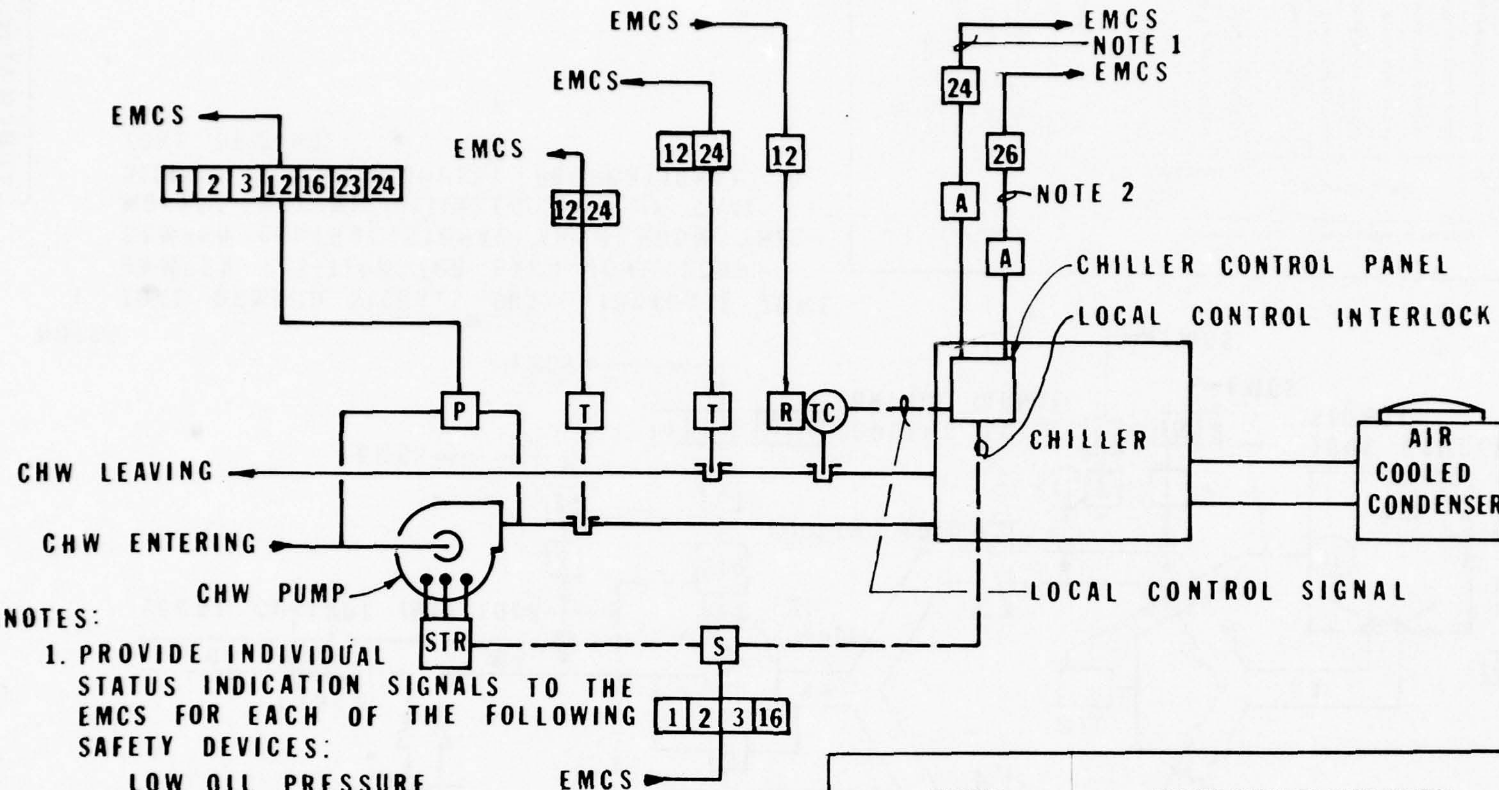
SCHEMATIC S—3



EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	●
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	●
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

TERMINAL REHEAT AIR HANDLER

SCHEMATIC S—4



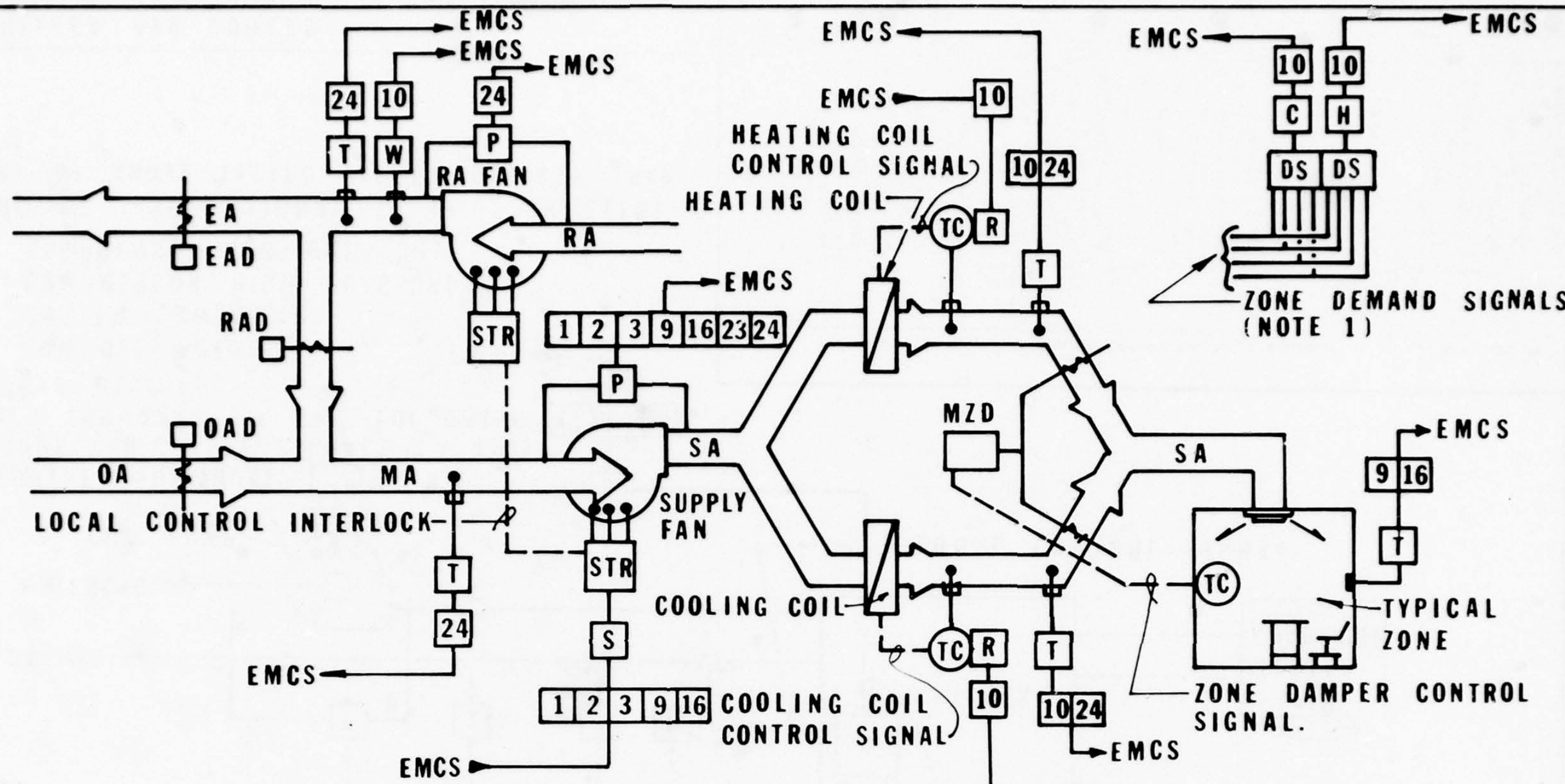
NOTES:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES:
   - LOW OIL PRESSURE
   - COOLER LOW TEMP.
   - COMPRESSOR HIGH PRESSURE
   - COMPRESSOR LOW PRESSURE
2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIP

Category	Subcategory	Function	No.	Applies
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	●
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	●
		INTERCOM	27	
			28	

CHILLER, AIR COOLED

SCHEMATIC | **S-5**



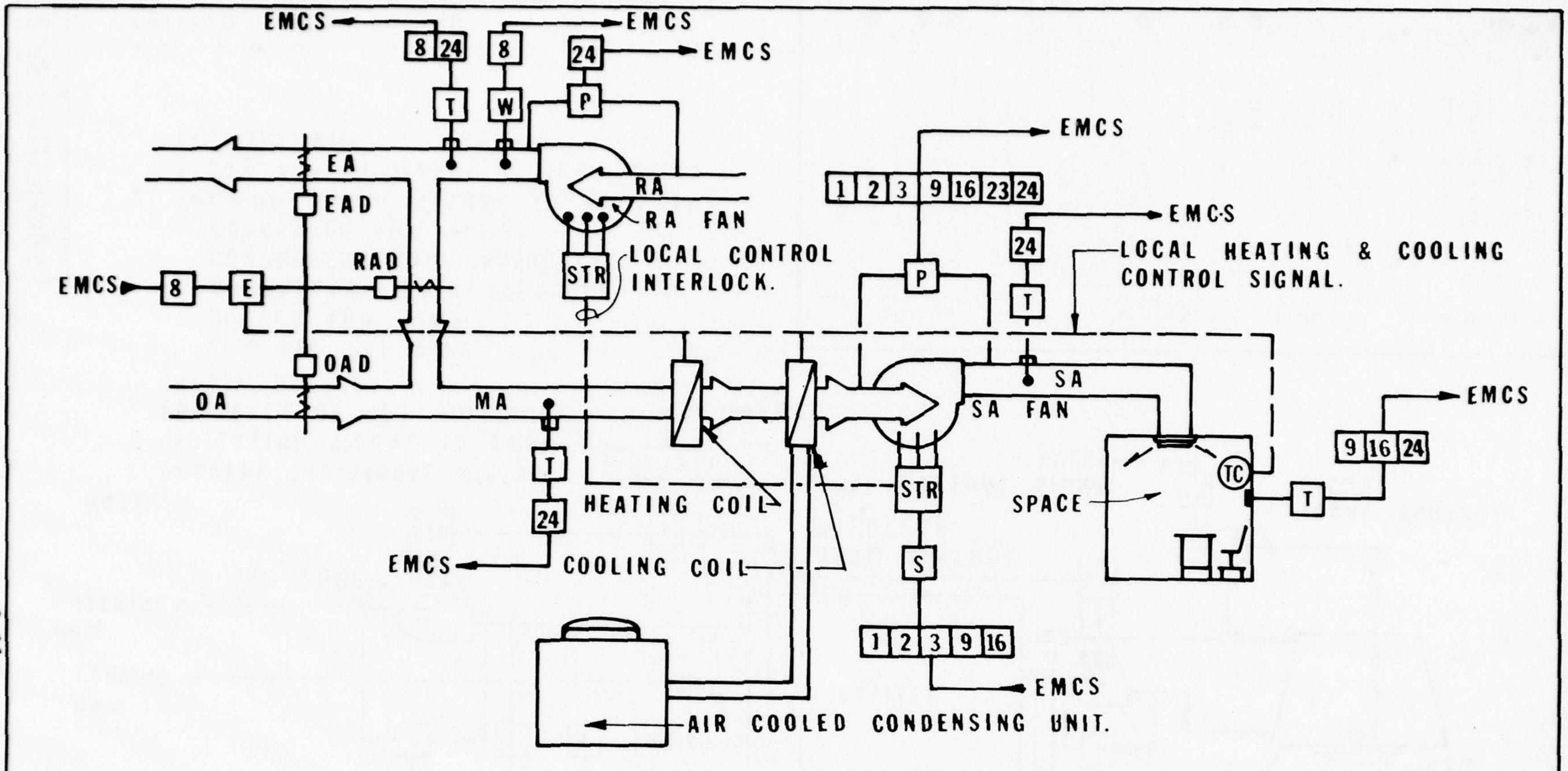
NOTES:

1. ZONE DEMAND SIGNALS SHALL INDICATE ZONE DAMPER POSITION FOR EACH ZONE. ZONE DAMPER CONTROL SIGNAL FROM ROOM THER-MOSTAT MAY BE UTILIZED ONLY IF THAT SIGNAL IS CONTINUOUSLY PROPORTIONAL TO ZONE DEMAND.

Category	Subcategory	No.	Function	Selected
EQUIPMENT ON/OFF		1	TIME SCHEDULED OPERATION	●
		2	DUTY CYCLING	●
	DEMAND LIMITING	3	START/STOP	●
		4	GENERATOR OPERATION	
		5	CHILLER LIMIT ADJUST	
		6		
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	7	WARM UP/NIGHT CYCLE	
		8	ENTHALPY ECONOMIZER	
	TEMPERATURE RESET	9	SPACE NIGHT SETBACK	●
		10	HOT/COLD DECK RESET	●
		11	REHEAT COIL RESET	
		12	CHILLED WATER RESET	
		13	COND. WATER RESET	
		14	O.A. SCHEDULE RESET	
		15		
		16	START/STOP OPTIMIZATION	●
	CENTRAL PLANT OPTIMIZATION	17	BOILER PROFILE & SELECT	
		18	CHILLER PROFILE & SELECT	
		19	PUMP SELECTION	
		20		
MONITORING		21	SECURITY FUNCTIONS	
		22	FIRE ALARM FUNCTIONS	
		23	MAINT. RUN TIME REPORTS	●
		24	TROUBLE DIAGNOSIS	●
		25	CRITICAL AREAS ALARMS	
		26	SAFETY ALARMS	
		27	INTERCOM	
		28		

MULTI ZONE AIR HANDLER

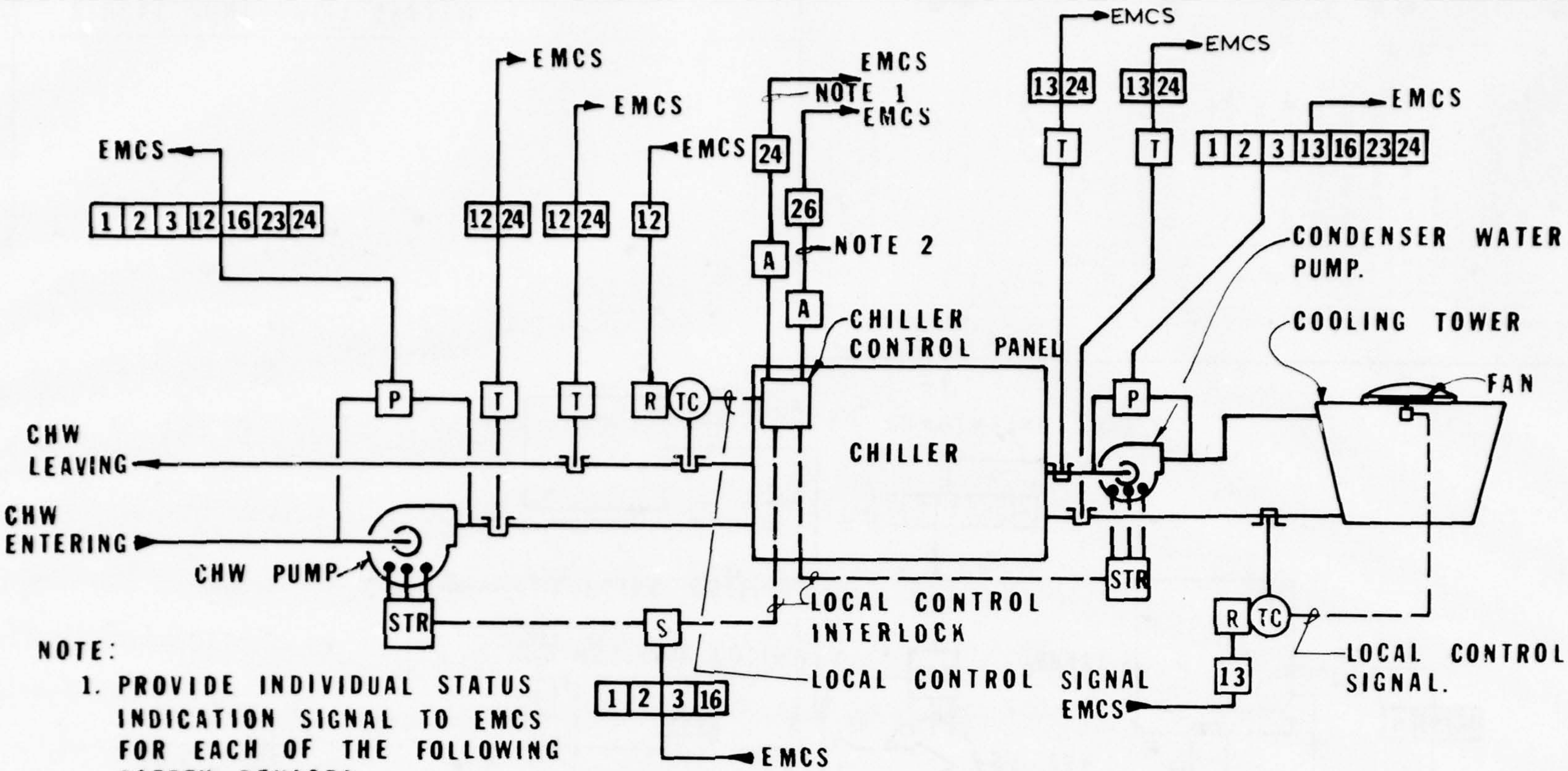
SCHEMATIC S-6



			No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	●
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

SINGLE ZONE SPLIT SYSTEM

SCHEMATIC S-7



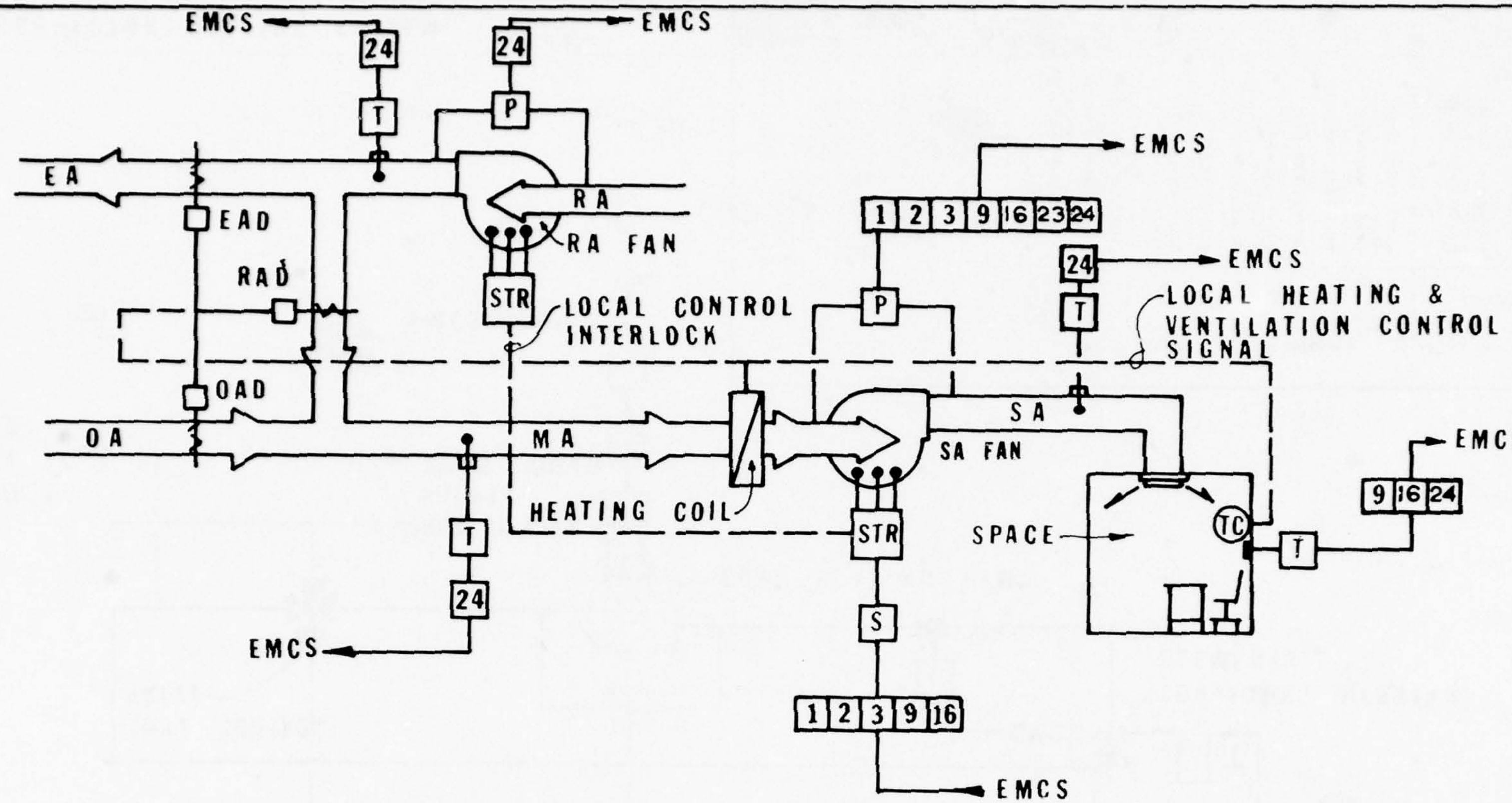
NOTE:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNAL TO EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES.
   - LOW OIL PRESSURE
   - COOLER LOW TEMP
   - COMPRESSOR HIGH PRESSURE
   - COMPRESSOR LOW PRESSURE
   - CONDENSER LOW TEMP
2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIP

		No.	Function	
EQUIPMENT ON/OFF		1	TIME SCHEDULED OPERATION	●
		2	DUTY CYCLING	●
	DEMAND LIMITING	3	START/STOP	●
		4	GENERATOR OPERATION	
		5	CHILLER LIMIT ADJUST	
		6		
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	7	WARM UP/NIGHT CYCLE	
		8	ENTHALPY ECONOMIZER	
	TEMPERATURE RESET	9	SPACE NIGHT SETBACK	
		10	HOT/COLD DECK RESET	
		11	REHEAT COIL RESET	
		12	CHILLED WATER RESET	●
		13	COND. WATER RESET	●
		14	O.A. SCHEDULE RESET	
		15		
		16	START/STOP OPTIMIZATION	●
	CENTRAL PLANT OPTIMIZATION	17	BOILER PROFILE & SELECT	
		18	CHILLER PROFILE & SELECT	
		19	PUMP SELECTION	
		20		
MONITORING		21	SECURITY FUNCTIONS	
		22	FIRE ALARM FUNCTIONS	
		23	MAINT. RUN TIME REPORTS	●
		24	TROUBLE DIAGNOSIS	●
		25	CRITICAL AREAS ALARMS	
		26	SAFETY ALARMS	●
		27	INTERCOM	
		28		

CHILLER, WATER COOLED

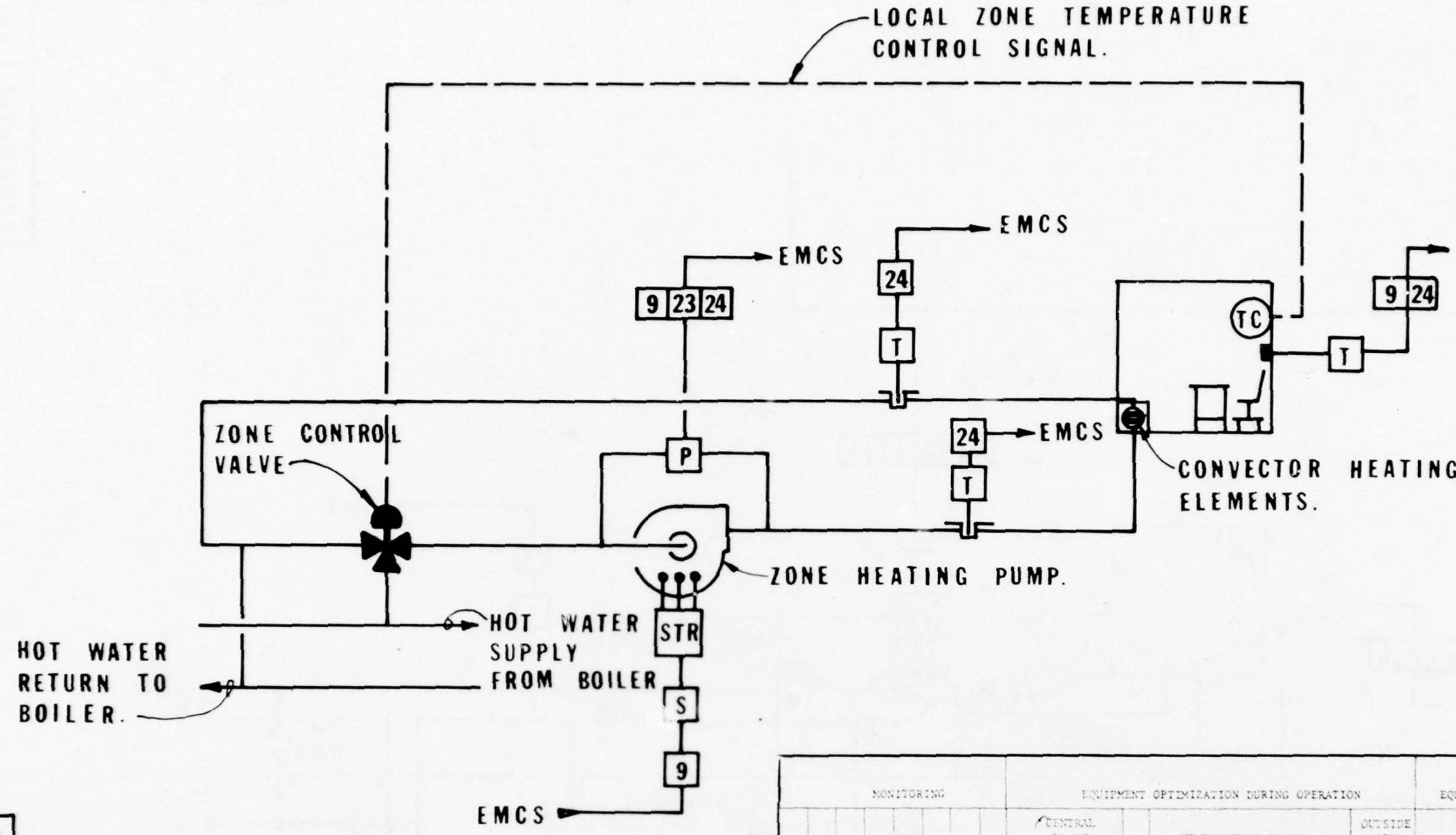
SCHEMATIC S—8



Category	Sub-category	Function	No.	Selected
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

HEATING AND VENTILATING UNIT

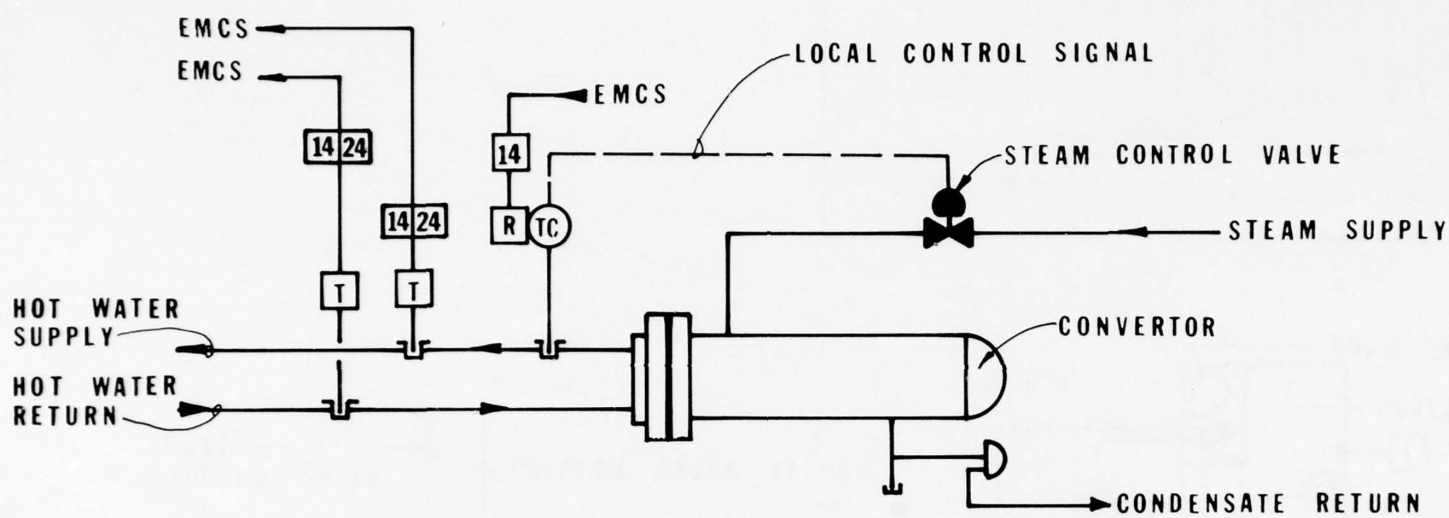
SCHEMATIC S—9



Category	Subcategory	Function	No.	Selected
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

CONVECTOR HEATING SYSTEM

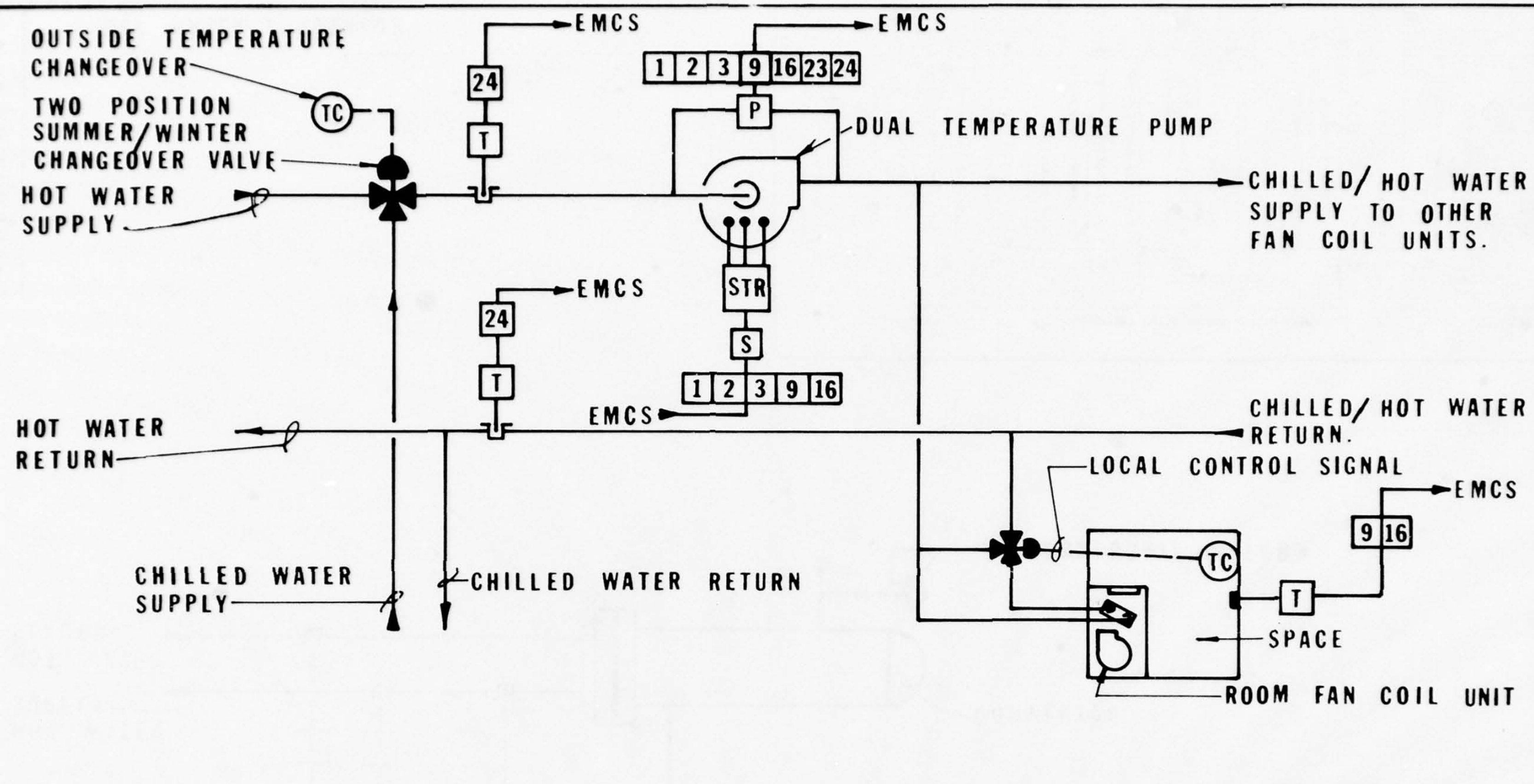
SCHEMATIC S—10



EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	●
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

HOT WATER CONVERTOR

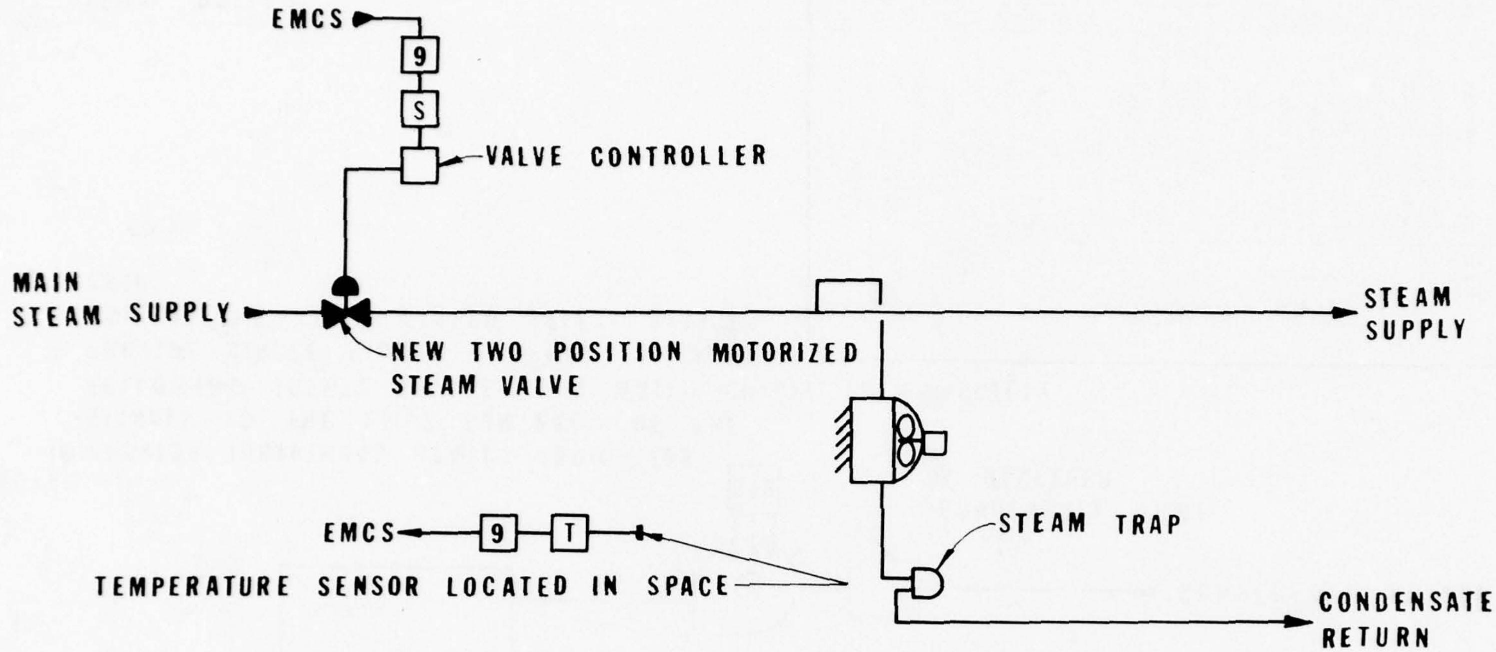
SCHEMATIC S—11



EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

TWO PIPE FAN COIL SYSTEM

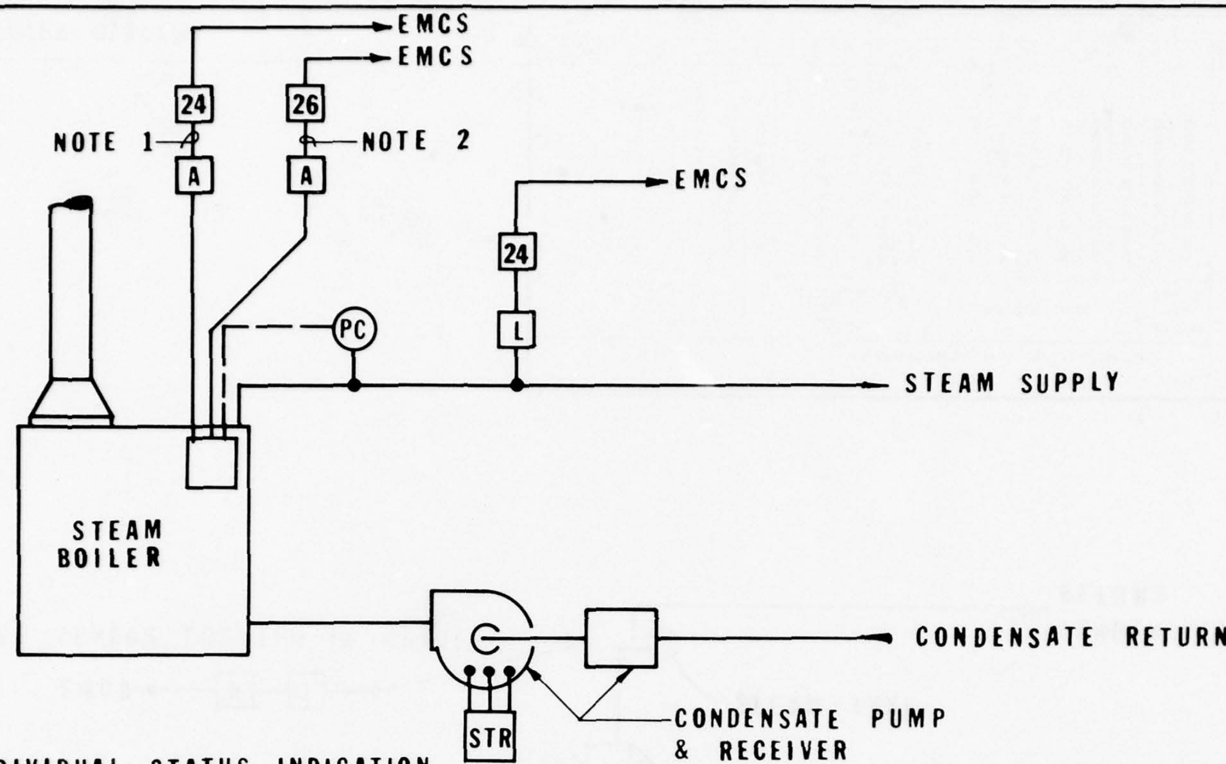
SCHEMATIC S-12



Category	Subcategory	No.	Function	
EQUIPMENT ON/OFF		1	TIME SCHEDULED OPERATION	
		2	DUTY CYCLING	
	DEMAND LIMITING	3	START/STOP	
		4	GENERATOR OPERATION	
		5	CHILLER LIMIT ADJUST	
		6		
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	7	WARM UP/NIGHT CYCLE	
		8	ENTHALPY ECONOMIZER	
	TEMPERATURE RESET	9	SPACE NIGHT SETBACK	●
		10	HOT/COLD DECK RESET	
		11	REHEAT COIL RESET	
		12	CHILLED WATER RESET	
		13	COND. WATER RESET	
		14	O.A. SCHEDULE RESET	
		15		
		16	START/STOP OPTIMIZATION	
	CENTRAL PLANT OPTIMIZATION	17	BOILER PROFILE & SELECT	
		18	CHILLER PROFILE & SELECT	
		19	PUMP SELECTION	
		20		
MONITORING		21	SECURITY FUNCTIONS	
		22	FIRE ALARM FUNCTIONS	
		23	MAINT. RUN TIME REPORTS	
		24	TROUBLE DIAGNOSIS	
		25	CRITICAL AREAS ALARMS	
		26	SAFETY ALARMS	
		27	INTERCOM	
		28		

STEAM UNIT HEATER SYSTEM

SCHEMATIC S—13



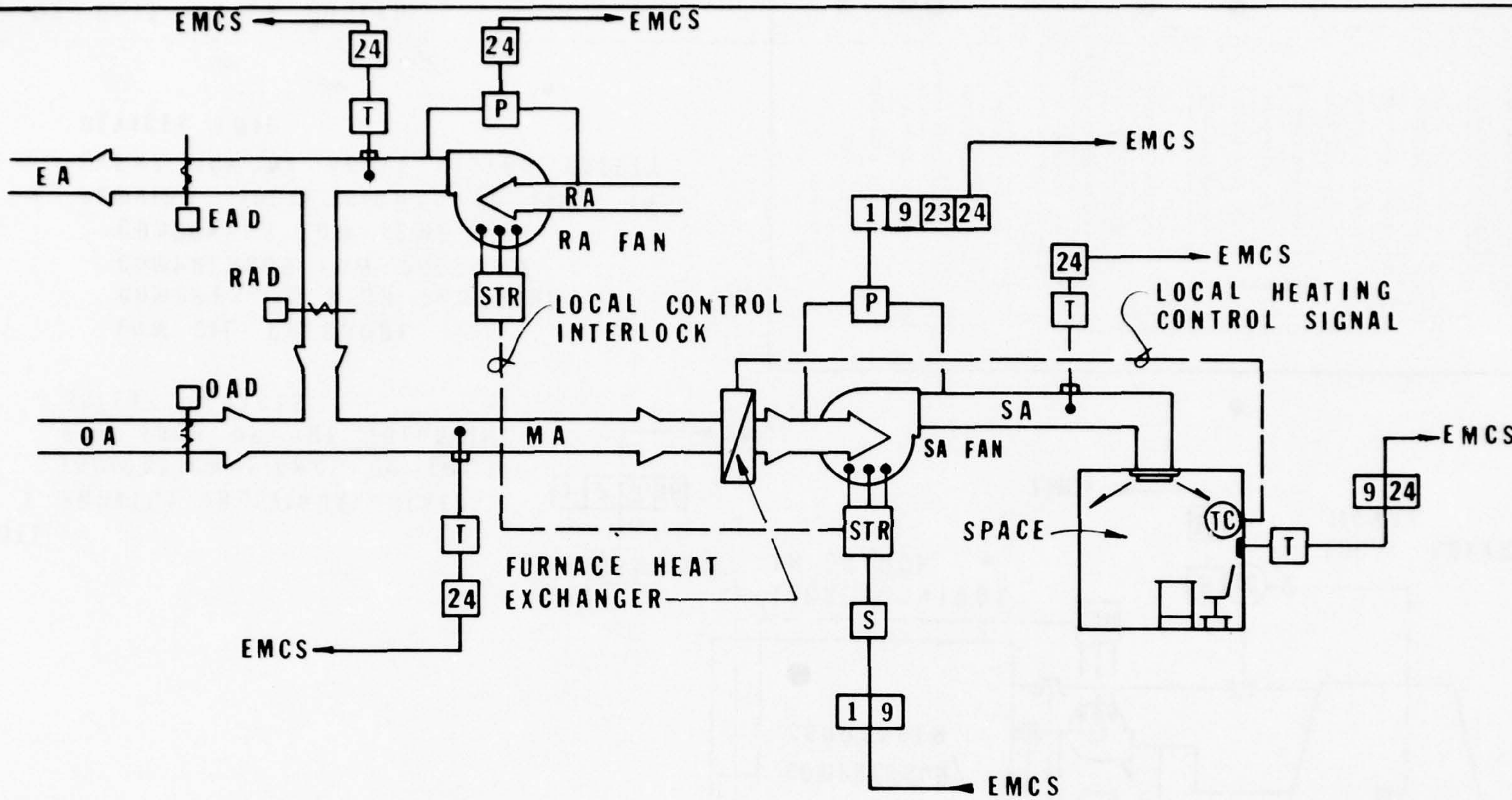
NOTES:

1. PROVIDE INDIVIDUAL STATUS INDICATION SIGNALS TO THE EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES: LOW WATER CUTOFF, FLAME SAFETY.
2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF THE ABOVE LISTED SAFETY DEVICES TRIP.

			No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	●
		INTERCOM	27	
			28	

STEAM BOILER

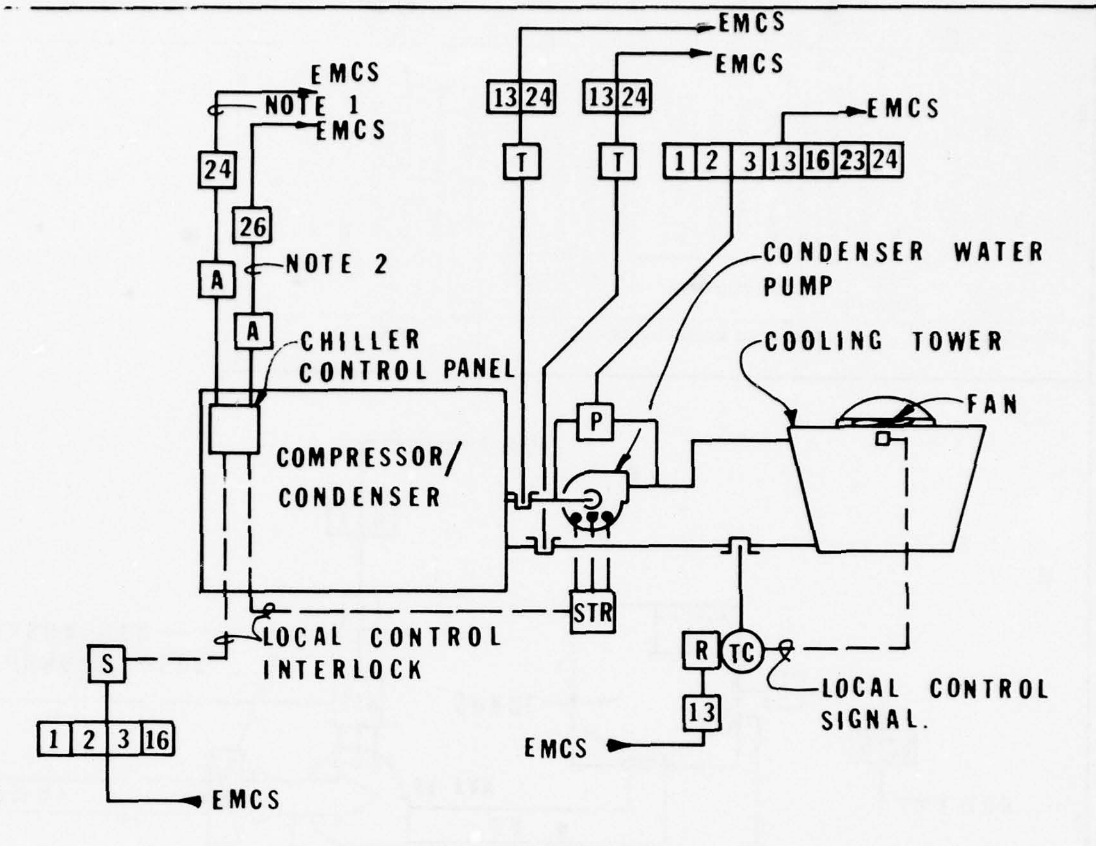
SCHEMATIC S—14



Category	Subcategory	Function	No.	Selected
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

DIRECT FIRED FURNACE

SCHEMATIC S-15



NOTE

1 PROVIDE INDIVIDUAL STATUS INDICATION SIGNAL TO EMCS FOR EACH OF THE FOLLOWING SAFETY DEVICES.

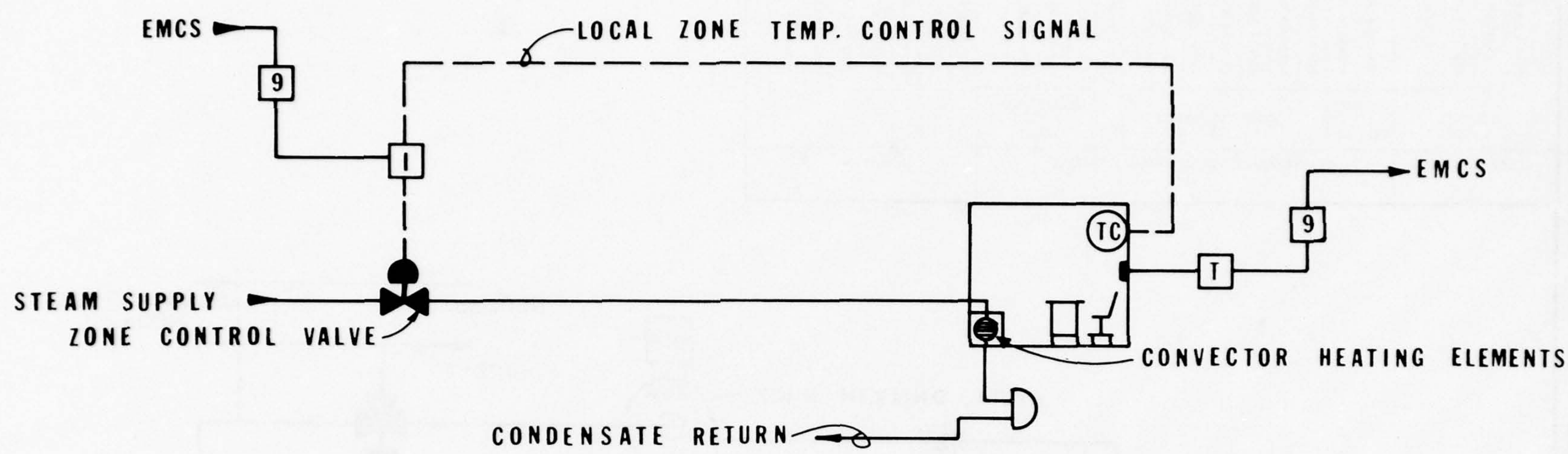
LOW OIL PRESSURE
COMPRESSOR HIGH PRESSURE
COMPRESSOR LOW PRESSURE
CONDENSER LOW TEMP.

2. PROVIDE SINGLE SIGNAL TO EMCS IN EVENT ANY OF ABOVE LISTED SAFETY DEVICES TRIP

Category	Subcategory	Function	No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	●
		DUTY CYCLING	2	●
	DEMAND LIMITING	START/STOP	3	●
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	●
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	●
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	●
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	●
		INTERCOM	27	
			28	

DX UNIT, WATER COOLED

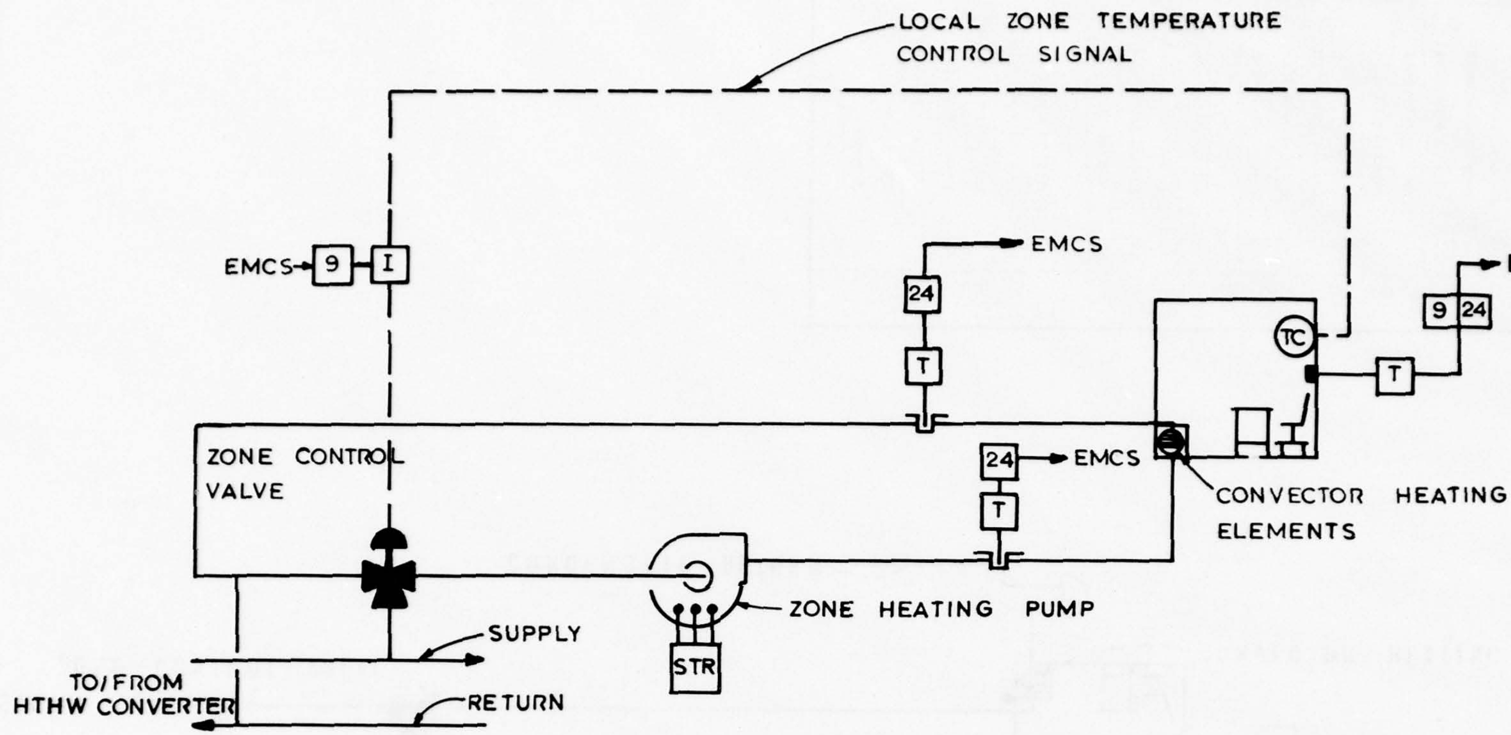
SCHEMATIC S—16



		No.	Function	
EQUIPMENT ON/OFF		1	TIME SCHEDULED OPERATION	
		2	DUTY CYCLING	
	DEMAND LIMITING	3	START/STOP	
		4	GENERATOR OPERATION	
		5	CHILLER LIMIT ADJUST	
		6		
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	7	WARM UP/NIGHT CYCLE	
		8	ENTHALPY ECONOMIZER	
	TEMPERATURE RESET	9	SPACE NIGHT SETBACK	●
		10	HOT/COLD DECK RESET	
		11	REHEAT COIL RESET	
		12	CHILLED WATER RESET	
		13	COND. WATER RESET	
		14	O.A. SCHEDULE RESET	
		15		
		16	START/STOP OPTIMIZATION	
	CENTRAL PLANT OPTIMIZATION	17	BOILER PROFILE & SELECT	
		18	CHILLER PROFILE & SELECT	
		19	PUMP SELECTION	
		20		
MONITORING		21	SECURITY FUNCTIONS	
		22	FIRE ALARM FUNCTIONS	
		23	MAINT. RUN TIME REPORTS	
		24	TROUBLE DIAGNOSIS	
		25	CRITICAL AREAS ALARMS	
		26	SAFETY ALARMS	
		27	INTERCOM	
		28		

STEAM CONVECTOR HEATING SYSTEM

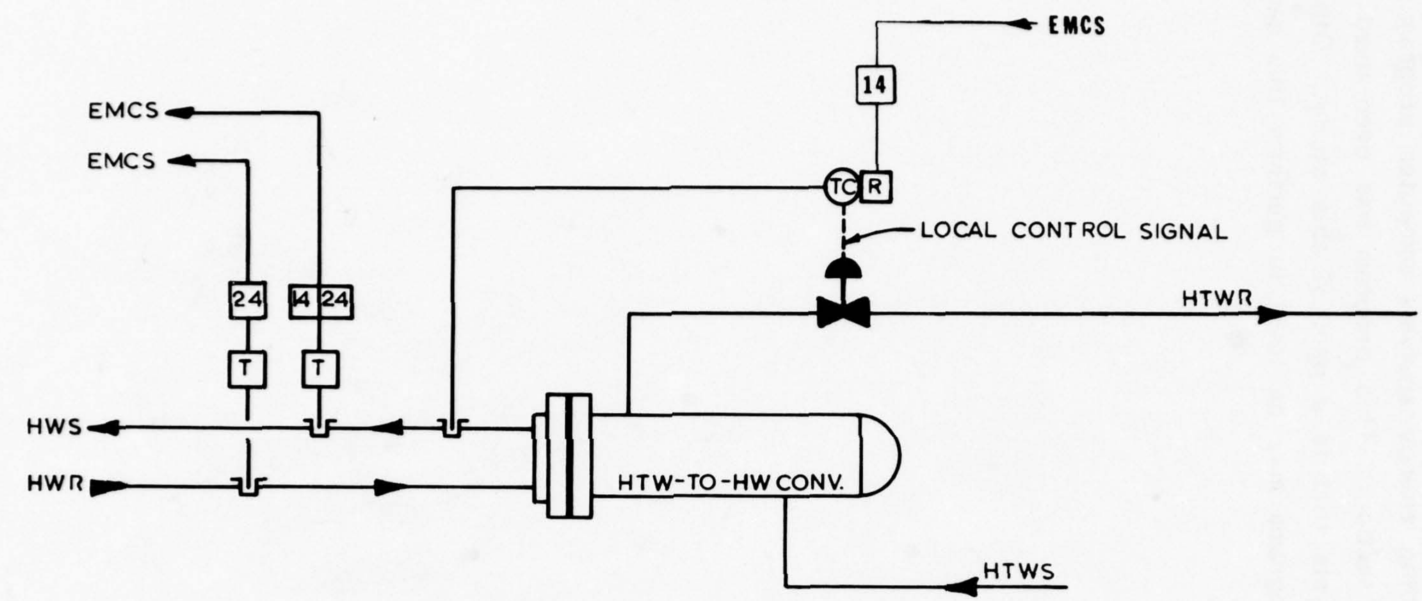
SCHEMATIC S—17



Category	Subcategory	Function	No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	●
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

HOT WATER CIRCUIT

SCHEMATIC S-18



			No.	
EQUIPMENT ON/OFF		TIME SCHEDULED OPERATION	1	
		DUTY CYCLING	2	
	DEMAND LIMITING	START/STOP	3	
		GENERATOR OPERATION	4	
		CHILLER LIMIT ADJUST	5	
			6	
EQUIPMENT OPTIMIZATION DURING OPERATION	OUTSIDE AIR CONTROL	WARM UP/NIGHT CYCLE	7	
		ENTHALPY ECONOMIZER	8	
	TEMPERATURE RESET	SPACE NIGHT SETBACK	9	
		HOT/COLD DECK RESET	10	
		REHEAT COIL RESET	11	
		CHILLED WATER RESET	12	
		COND. WATER RESET	13	
		O.A. SCHEDULE RESET	14	●
			15	
		START/STOP OPTIMIZATION	16	
	CENTRAL PLANT OPTIMIZATION	BOILER PROFILE & SELECT	17	
		CHILLER PROFILE & SELECT	18	
		PUMP SELECTION	19	
			20	
MONITORING		SECURITY FUNCTIONS	21	
		FIRE ALARM FUNCTIONS	22	
		MAINT. RUN TIME REPORTS	23	
		TROUBLE DIAGNOSIS	24	●
		CRITICAL AREAS ALARMS	25	
		SAFETY ALARMS	26	
		INTERCOM	27	
			28	

HTW-TO-HW CONVERTOR

SCHEMATIC S-19

2.3 ANALYSIS TECHNIQUES

Note: The E-CUBE 75 building energy analysis computer program is referred to throughout this section. This program has been used to perform the feasibility analysis that is a part of this study. Other building energy analysis programs may be used to perform this same analysis.

2.3.1 SYSTEM: HOT WATER BOILER
Schematic #S-1

FUNCTION: O.A. SCHEDULE RESET, #14

Costs:	Temperature Indication	2@ \$300. = \$ 600.
	Controller Reset	1@ \$650. = \$ 650.
		\$1250.

Savings:

Boiler temperature reset saves by reducing heat losses through the heating system and flue gases and by providing more exact control at the end use point. This last item provides savings by reducing overheating of spaces at less than maximum loads due to control valve insensitivity in those operating ranges. No exact means of quantifying these savings is known, however experience indicates these savings should be a function of the annual hours of boiler operation and the total capacity of the boiler. An increase of 2% in annual operating efficiency will be assumed.

$S = H \times E \times I \times \text{Therms/MBTU}$

Where

S = annual savings, Therms
H = annual number of hours boiler is fired
E = efficiency increase, = 0.02
I = maximum input capacity of boiler, MBH
Therms/MBTU = 100

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: Differential pressure switch status indication 1@ \$300. = \$300.

Savings:

By scheduling maintenance based on actual operation, assume the EMCS is able to save one man-visit per heating season to the boiler. Assume this man-visit is 2 hours in duration.

S = 2 man hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	2@ \$300. = \$ 600.
	Differential pressure switch status indication	1@ \$300. = \$ 300.
	Alarm contact points	3@ \$250. = \$ 750.
		\$1650.

Savings:

Assume total of 2 hours saved per year of occupant and maintenance personnel time in conveying alarm information.

S = 2 man-hours

SYSTEM: HOT WATER BOILER
Schematic #S-1

FUNCTION: SAFETY ALARM, #26

Costs: Alarm contact points 1@ $250. = $250.

Savings:

Assume total of 2 hours saved per year of occupant and maintenance personnel time in conveying alarm information.

S = 2 man-hours

2.3.2 SYSTEM: DX UNIT, AIR COOLED
Schematic #S-2

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with
On/Off Status Indication 1@ $450. = $450.

Savings:
Electrical input to this system is directly related to cooling load since both the compressors and condenser fans cycle in response to cooling load. Because time scheduled operation of this system only delays occurrence of cooling load, and actual reduction of cooling load, such as outside air shutoff, is a result of air system shutdown, no net energy savings will be estimated from this function.

S = $0.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Because duty cycling only delays the occurrence of cooling load, no net energy savings will be estimated from this function.

S = $0.

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume by using a rotating group load shed scheme that an average of 25% of the KW load of this system may be shed under peak conditions:

$$S = (HP1 + HP2) \times L \times KW/HP \times 0.25 \times M$$

Where
S = annual savings, KW
HP1 = total compressor motor nameplate horsepower
HP2 = total condenser fan motor nameplate horsepower
L = load factor, combination of motor efficiency and actual actual motor loading, use 0.8
KW/HP = conversion factor from horsepower to kilowatts, use 0.746
M = Number of months system operates

SYSTEM: DX UNIT, AIR COOLED
Schematic #S-2

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
For same reasons listed under TIME SCHEDULED OPERATION, no net energy savings will be estimated from this function.

S = $0.

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: ON/OFF STATUS Indication 1@ $300. = $300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	ON/OFF Status Indication	1@ $300. =	$ 300.
	Alarm Contact Points	3@ $250. =	$ 750.
			$1050.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: SAFETY ALARMS, #26

Costs: Alarm Contact Point, 1@ $250. = $250.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.3 SYSTEM: SINGLE ZONE AIR HANDLER
Schematic #S-3

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with differential pressure switch status indication 1@ $450. = $450.

Savings:

Simulate building loads and system operation using ECUBE. In initial run assume that systems run 24 hr/day, 7 day/week. In second run assume that systems run only during occupied hours plus one hour in the morning for warm up or cool down. Do not include fan KW in ECUBE runs so that results are representative only of heating and cooling energy reduction. This heating and cooling energy savings can then be proportioned on a per cfm basis to other similar systems. Fan energy savings should then be added by multiplying the fan KW by the number of hours of shutdown for the system. Thus:

Cooling Savings = Difference in electrical consumption of ECUBE runs.
Heating Savings = difference in heating consumption of ECUBE runs.
Fan Savings = HP x L x KW/HP x (8760 - H)

Where
HP = total fan motor nameplate horsepower
L = load factor, use 0.8
KW/HP = 0.746
H = number of hours of system operation

If the air handler is presently operating around the clock the above calculated savings may be used directly. If however the unit is currently started and stopped by a time switch, full credit can not be taken for the above savings for the EMCS. Determining what savings may be attributed to the EMCS becomes a function of the reliability of the time switch system. Time switches can be effective devices for the reduction of energy consumption, however, they have several disadvantages. They do not take into account holiday operation, seasonal changes, or daily weather variations. They are also easily tampered with, bypassed, or overridden. The pins which activate actions may slide, thus causing system operation and energy consumption at unnecessary times. They must be checked often to insure proper operation and must be reset manually everytime a power outage occurs for any appreciable time period. The EMCS is capable of performing the same operations as the time switches but without most of the difficulties described, since it is not within the reach of tampering, and system operations are monitored constantly by the console operator.

SYSTEM: SINGLE ZONE AIR HANDLER
Schematic #S-3

An exact method of analyzing the energy savings of an EMCS over a time switch system is not available. The survey of buildings indicates that some buildings with time switches are operating properly while others have been overridden or set improperly. With time clocks, a system that is operating properly one day may be operating improperly the next day. This is not true with the EMCS since modifications to operations must be made by the EMCS operators. For these reasons, the EMCS savings over time switches will be estimated by multiplying an efficiency factor times the heating, cooling, and fan savings estimated above. The efficiency factor will be assumed to equal 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume the system may be shut down for an average of 10 minutes per hour. The savings resulting from this function are fan energy and outside air heating and cooling energy. Outside air loads are difficult to determine since they actually depend on space load conditions. If there is a net cooling load in the space, and the outside air is below 75°F, the outside air actually reduces energy consumption. Also actual outside air quantities may be very different from design quantities, with no practical means of determining what the actual quantity is. Therefore outside air load savings will be ignored in duty cycling analysis.

$S = HP \times L \times 10/60 \times H \times KW/HP$
Where
HP = total fan motor nameplate horsepower
10/60 = fraction of time system is shut down
H = <u>required</u> annual hours of system operation
L = 0.8 load factor
KW/HP = 0.746

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume that system can be shed 25% of time under peak load conditions (same period as duty cycling).

SYSTEM: SINGLE ZONE AIR HANDLER
Schematic #S-3

$S = HP \times L \times KW/HP \times 0.25 \times M$
Where
HP = total fan motor nameplate horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: ENTHALPY ECONOMIZER, #8

Costs:	Return air temperature indication	1@ $300.	= $ 300.
	Return air relative humidity indication	1@ $500.	= $ 500.
	Enthalpy changeover interface	1@ $570.	= $ 570.
			$1370.

Savings:
Simulate building loads and enthalpy economizer operation with ECUBE. In initial run assume that no economizer is operable, in second run simulate savings from conventional dry bulb economizer changeover, and in third run simulate savings from enthalpy economizer operation. All runs should be made assuming the system is operating the minimum number of hours necessary. Savings may be proportioned for similar systems on a per cfm basis.

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Space temperature indication	1@ $300.	= $300.
	Start/Stop interface with Differential pressure switch status indication	1@ $450.	= $450.
			$750.

Savings:
Use ECUBE to simulate thermostat setup/setback operation. Assume a summer setup of 5°F and a winter setback of 15°F. These values have been chosen because the night setback function is generally only used where sensitive equipment or materials are present and the system cannot be shutdown by a time scheduled operation function.

FUNCTION: START/STOP OPTIMIZATION, #16

Cost: Same as SPACE NIGHT SETBACK = $750.

Savings:
Assume an average of 1/2 hour of fan operation per occupied day may be saved by this function. Assume no net heating or cooling energy is saved.

SYSTEM: SINGLE ZONE AIR HANDLER
Schematic #S-3

$$S = HP \times L \times KW/HP \times 0.5 \times OD$$

Where
HP = Total fan motor nameplate horsepower
L = load factor, use 0.8
KW/HP = 0.746
OD = number of occupied days per year

FUNCTION: MAINTENANCE RUN TIME REPORT, #23

Costs:	Differential pressure switch status indication	1@ $300. = $300.

Savings:
Assume same as savings for this function on schematic S-1.

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	4@ $300. = $1200.
	Differential pressure switch status indication	1@ $300. = $ 300.
		$1500.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.4 SYSTEM: TERMINAL REHEAT AIR HANDLER
Schematic #S-4

FUNCTION: TIME SCHEDULE OPERATION, #1

Costs: Start/Stop Interface with
Differential Pressure Switch 1@ $450. = $450.

Savings:
Use same approach as that described for this function on schematic #S-3 except include reheat penalty in ECUBE input; thus:

Cooling Savings = difference in electrical consumption of ECUBE runs
Heating Savings = difference in heating consumption of ECUBE runs
Fan Savings = HP x L x KW/HP x (8760-H)

If the system is presently started and stopped via a time switch multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Use same approach as that described for this function on schematic #S-3

S = HP x L x KW/HP x 10/60 x H

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATIONS = $450.

Savings:
Use same approach as that described for this function on schematic #S-3.

S = HP x L x KW/HP x 0.25 x M

FUNCTION: ENTHALPY ECOMONIZER, #8

Costs: Same as those for this function on schematic #S-3 = $1370.

Savings:
Use same approach as that described for this function on schematic #S-3. Include reheat penalty in ECUBE input.

FUNCTION: SPACE NIGHT SETBACK, #9

Cost: Same as those for this function on schematic #S-3 = $750.

Savings:
Use same approach as that described for this function on schematic #S-3. Include reheat penalty in ECUBE input.

SYSTEM: TERMINAL REHEAT AIR HANDLER
Schematic #S-4

FUNCTION: REHEAT COIL RESET, #11

Costs:	Temperature indication	1@ $300.	= $300.
	Controller Reset device	1@ $650.	= $650.
	Relative humidity indication	1@ $500.	= $500.
	Zone greatest cooling selector	1@ $450.	= $450.
			$1900.

Savings:
Simulate system operation with ECUBE. ECUBE does not have simulation routines necessary to select the zone with the greatest cooling demand and then calculate the necessary cooling coil leaving temperature. In order to approximate the savings from this function, run ECUBE assuming an average increase in cooling coil temperature of 5°F above the temperature used in the initial run.

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as those for this function on schematic #S-3 = $750.

Savings:
Use same approach as that described for this function on schematic #S-3.

$S = HP \times L \times KW/HP \times 0.5 \times OD$

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: Differential pressure switch status indication = $300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	3@ $300.	= $ 900.
	Differential pressure switch status indication	1@ $300.	= $ 300.
			$1200.

Savings:
Assume same as for this function on schematic S-1:

S = 2 man-hours

2.3.5 SYSTEM: CHILLER, AIR COOLED
Schematic #S-5

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with Differential Pressure Switch 1@ $450. = $450.

Savings:

Assume electrical input to chiller and condenser is proportional to cooling load as described for this function on schematic S-2. Savings will result from chilled water pump shutdown:

$S = HP \times L \times KW/HP \times (8760-H)$

Where

HP = chilled water pump motor horsepower

L = load factor, 0.8

KW/HP = 0.746

H = number of hours of system operation

If system is presently time clock controlled, multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:

Savings will occur from chilled water pump shutdown:

$S = HP \times L \times KW/HP \times H \times 10/60$

Where

HP = chilled water pump motor horsepower

L = load factor, 0.8

KW/HP = 0.746

H = number of hours of system operation

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

SYSTEM: CHILLER, AIR COOLED
Schematic #S-5

Savings:
Savings similar to this function on schematic S-2 except for addition of chilled water pump horsepower.

S = (HP1 + HP2 + HP3) x L x KW/HP x 0.25 x M
Where
HP1 = total compressor horsepower
HP2 = total condenser fan horsepower
HP3 = total chilled water pump horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: CHILLED WATER RESET, #12

Costs:	Temperature indication	2@ $300. =	$ 600.
	Reset controller	1@ $650. =	$ 650.
	Differential pressure switch status	1@ $300. =	$ 300.
			$1550.

Savings:
Approximately 1.5% efficiency increase may be obtained by increasing the average chilled water temperature 1°F. Assume the EMCS is capable of obtaining an average increase of 2°F. in chilled water temperature, thus a resultant savings of 3% of compresser and condenser fan energy should be realized. To conservatively approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hour. Savings resulting are:

S = T x 1000 hrs. x 1 KWH/ton-hr x 0.03
Where
T = chiller capacity, tons

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume saving 1/2 hour of chilled water pump operation per day of operation:

S = HP x L x KW/HP x 0.5 x 0
Where
HP = pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
0 = days of operation

SYSTEM: CHILLER, AIR COOLED
Schematic #S-5

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: Differential pressure switch status 1@ $300. = $300.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Ccsts:	Differential pressure switch status	1@ $300. = $ 300.
	Temperature indication	2@ $300. = $ 600.
	Alarm contact points	4@ $250. = $1000.
		$1900.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

FUNCTION: SAFETY ALARMS, #26

Costs: Alarm contact point, 1@ $250. = $250.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

2.3.6 SYSTEM: MULTIZONE AIR HANDLER
Schematic #S-6

FUNCTION: TIME SCHEDULE OPERATION, #1

Cost: Start/Stop Interface with
Differential Pressure Switch 1@ $450. = $450.

Savings:
Use same approach as that described for this function on schematic #S-3 except include hot/cold duct mixing penalty in ECUBE input; thus:

Cooling Savings = difference in electrical consumption of ECUBE runs
Heating Savings = difference in heating consumption of ECUBE runs
Fan Savings = HP x L x KW/HP x (8760-H)

If the system is presently started and stopped via a time switch multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Use same approach as that described for this function on schematic #S-3

$$S = HP \times L \times KW/HP \times 10/60 \times H$$

FUNCTION: DEMAND LIMITING START/STOP, #3

Cost: Same as TIME SCHEDULED OPERATIONS = $450.

Savings:
Use same approach as that described for this function on schematic #S-3.

$$S = HP \times L \times KW/HP \times 0.25 \times M$$

FUNCTION: SPACE NIGHT SETBACK, #9

Costs: Same as those for this function on schematic #S-3 = $750.

Savings:
Use same approach as that described for this function on schematic #S-3. Include hot/cold deck mixing penalty in ECUBE input.

SYSTEM: MULTIZONE AIR HANDLER
Schematic #S-6

FUNCTION: HOT/COLD DECK RESET, #10

Costs:

Temperature indication	2@ $ 300.	= $ 600.
Controller Reset device	2@ $ 650.	= $1300.
Relative humidity indication	1@ $ 500.	= $ 500.
Zone greatest cooling selector	1@ $ 450.	= $ 450.
Zone greatest heating selector	1@ $ 450.	= $ 450.
		$3300.

Savings:

Simulate system operation with ECUBE. ECUBE does not have simulation routines necessary to select the zones with the greatest demand and then calculate the necessary hot/cold deck leaving temperatures. In order to approximate the savings from this function, run ECUBE assuming an average decrease in cooling coil/heating coil temperature difference of 5°F compared to the temperature difference used in the initial run.

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as those for this function on schematic #S-3 = $750.

Savings:

Use same approach as that described for this function on schematic #S-3.

$$S = HP \times L \times KW/HP \times 0.5 \times OD$$

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: Differential pressure switch status indication = $300.

Savings:

Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:

Temperature indication	4@ $300.	= $1200.
Differential pressure switch status indication	1@ $300.	= $ 300.
		$1500.

Savings:

Assume same as for this function on schematic S-1:

S = 2 man-hours

2.3.7 SYSTEM: SINGLE ZONE SPLIT SYSTEM
Schematic #S-7

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with differential pressure switch status indication 1@ $450. = $450.

Savings:
Use same approach as that described for this function on Schematic #S-3. If the system is presently time switch controlled, multiply the calculated savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume the system may be shut down for an average of 15 minutes per hour. The savings resulting from this function are fan energy and outside air heating and cooling energy. Outside air loads are difficult to determine since they actually depend on space load conditions. If there is a net cooling load in the space, and the outside air is below 75°F, the outside air actually reduces energy consumption. Also actual outside air quantities may be very different from design quantities, with no practical means of determining what the actual quantity is. Therefore outside air load savings will be ignored in duty cycling analysis.

$S = HP \times L \times 15/60 \times H \times KW/HP$

Where
HP total fan motor nameplate horsepower
15/60 = fraction of time system is shut down
H = required annual hours of system operation
L = 0.8 load factor
KW/HP = 0.746

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume system can be shed 25% of time under peak load conditions (same period as duty cycling).

SYSTEM: SINGLE ZONE SPLIT SYSTEM
Schematic #S-7

$S = (HP1 + HP2 + HP3) \times L \times KW/HP \times 0.25 \times M$
Where
HP1 = total fan motor nameplate horsepower
HP2 = total compressor motor nameplate horsepower
HP3 = total condenser fan motor nameplate horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: ENTHALPY ECONOMIZER, #8

Costs:	Return air temperature indication	1@ $300. = $ 300.
	Return air relative humidity indication	11@ $500. = $ 500.
	Enthalpy changeover interface	1@ $570. = $ 570.
		$1370.

Savings:
Simulate building loads and enthalpy economizer operation with ECUBE. In initial run assume no economizer is operable, in second run simulate savings from conventional dry bulb economizer changeover, and in third run simulate savings from enthalpy economizer operation. All runs should be made assuming the system is operating the minimum number of hours necessary. Savings may be proportioned for similar systems on a per cfm basis.

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Space temperature indication	1@ $300. = $300.
	Start/Stop interface with differential pressure switch status indication	1@ $450. = $450.
		$750.

Savings:
Utilize ECUBE to simulate thermostat setup/setback operation. Assume a summer setup of 5°F and a winter setback of 15°F. These values have been chosen because the night setback function is generally only used where sensitive equipment or materials are present and the system cannot be shutdown by a time scheduled operation function.

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as SPACE NIGHT SETBACK = $750.

Savings:
Assume an average of 1/2 hour of fan operation per occupied day may be saved by this function. Assume no net heating or cooling energy is saved.

SYSTEM: SINGLE ZONE SPLIT SYSTEM
Schematic #S-7

$S = HP \times L \times KW/HP \times 0.5 \times OD$
Where
HP = Total fan motor nameplate horsepower
L = load factor, use 0.8
KW/HP = 0.746
OD = number of occupied days per year

FUNCTION: MAINTENANCE RUN TIME REPORT, #23

Costs:	Differential pressure switch status indication	1@ \$300. = \$300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	4@ \$300. = \$1200.
	Differential pressure switch status indication	1@ \$300. = \$ 300.
		\$1500.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

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2.3.8 SYSTEM: CHILLER, WATER COOLED
Schematic #S-8

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with two Differential Pressure Switches 1@ $750. = $750.

Savings:
Assume electrical input to chiller and cooling tower fan is proportional to cooling load as described for this function on schematic S-2. Savings will result from chilled water pump and condenser water pump shutdown:

S = (HP1 + HP2) x L x KW/HP x (8760-H)
Where
HP1 = chilled water pump motor horsepower
HP2 = condenser water pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
H = number of hours of system operation

If system is presently time clock controlled, multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $750.

Savings:
Savings will occur from chilled water pump and condenser water pump shutdown:

S = (HP1 + HP2) x L x KW/HP x H x 10/60
Where
HP1 = chilled water pump motor horsepower
HP2 = condenser water pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
H = number of hours of system operation

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $750.

Savings:
Savings similar to this function on schematic S-2 except for addition of chilled water pump, condenser water pump, and cooling tower fan horsepower.

SYSTEM: CHILLER, WATER COOLED
Schematic #S-8

$$S = (HP1 + HP2 + HP3 + HP4) \times L \times KW/HP \times 0.25 \times M$$

Where
HP1 = total compressor horsepower
HP2 = total cooling tower fan horsepower
HP3 = total chilled water pump horsepower
HP4 = condenser water pump horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: CHILLED WATER RESET, #12

Costs:	Temperature indication	2@ \$300. =	\$600.
	Reset controller	1@ \$650. =	\$650.
	Differential pressure switch status	1@ \$300. =	\$300.
			\$1550.

Savings:

Approximately 1.5% efficiency increase may be obtained by increasing the average chilled water temperature 1°F. Assume the EMCS is capable of obtaining an average increase of 2°F. in chilled water temperature, thus a resultant savings of 3% of compresser and cooling tower fan energy should be realized. To conservatively approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hour. Savings resulting are:

$$S = T \times 1000 \text{ hrs.} \times 1 \text{ KWH/ton-hr} \times 0.03$$

Where
T = chiller capacity, tons

FUNCTION: CONDENSER WATER RESET, #13

Costs:	Temperature indication	2@ \$300. =	\$600.
	Reset controller	1@ \$650. =	\$650.
	Differential pressure switch status	1@ \$300. =	\$300.
			\$1550.

Savings:

Approximately 1.5% efficiency increase may be obtained by decreasing the average condenser water temperature 1°F. Assume the EMCS is capable of obtaining an average decrease of 3°F. in condenser water temperature, thus a resultant savings of 4.5% of compressor energy should be realized. To conservatively approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hr. Savings resultings are:

SYSTEM: CHILLER, WATER COOLED
Schematic #S-8

$$S = T \times 1000 \text{ hrs} \times 1 \text{ KWH/ton-hr} \times 0.045$$

Where
T = chiller capacity, tons

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as TIME SCHEDULED OPERATION = $750.

Savings:
Assume saving 1/2 hour of chilled water pump and condenser water pump operation per day of operation:

$$S = (HP1 + HP2) \times L \times KW/HP \times 0.5 \times 0$$

Where
HP1 = chilled pump motor horsepower
HP2 = condenser water pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
0 = days of operation

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs: Differential pressure switch status 2@ $300. = $600.

Savings:
Same as this function or schematic S-2

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Differential pressure switch status	2@ $300. = $ 600.
	Temperature indication	4@ $300. = $1200.
	Alarm contact points	5@ $250. = $1250.
		$3050.

Savings:
Same as this function on schematic S-2

S = 2 man-hours

FUNCTION: SAFETY ALARMS, #26

Costs: Alarm contact point, 1@ $250. = $250.

Savings:
Same as this function on schematic S-2

S = 2 man-hours

2.3.9 SYSTEM: HEATING AND VENTILATING UNIT
Schematic #S-9

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with differential pressure switch status indication 1@ $450. = $450.

Savings:
Use same approach as that described for this function on Schematic #S-3. Include heating only in ECUBE analysis. If the system is presently time switch controlled, multiply the calculated savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume the system may be shut down for an average of 10 minutes per hour. The savings resulting from this function are fan energy and outside air heating energy. Outside air loads are difficult to determine because they actually depend on space load conditions. Also actual outside air quantities may be very different from design quantities, with no practical means of determining what the actual quantity is. Therefore outside air load savings will be ignored in duty cycling analysis.

S = HP x L x 10/60 x H x C x KW/HP
Where
HP = total fan motor nameplate horsepower
10/60 = fraction of time system is shut down
H = <u>required</u> annual hours of system operation
C = electrical cost, $/KWH
L = 0.8 load factor
KW/HP = 0.746

FUNCTION: DEMAND LIMITING START/STOP, #3
Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume that system can be shed 25% of time under peak load conditions (same period as duty cycling).

SYSTEM: HEATING AND VENTILATING UNIT
Schematic #S-9

$$S = HP \times L \times KW/HP \times 0.25 \times M$$

Where
HP = total fan motor nameplate horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: SPACE NIGHT SETBACK, #9

Costs: Space temperature indication	1@ $300.	= $300.
Start/Stop interface with differential pressure switch status indication	1@ $450.	= $450.
		$750.

Savings:
Use ECUBE to simulate thermostat setup/setback operation.
Assume a winter setback of 15°F.

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as SPACE NIGHT SETBACK = $750.

Savings:
Assume an average of 1/2 hour of fan operation per occupied day may be saved by this function. Assume no net heating energy is saved.

$$S = HP \times L \times KW/HP \times 0.5 \times OD$$

Where
HP = Total fan motor nameplate horsepower
L = load factor, use 0.8
KW/HP = 0.746
OD = number of occupied days per year

FUNCTION: MAINTENANCE RUN TIME REPORT, #23

Costs: Differential pressure switch status indication: 1@ $300. = $300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

SYSTEM: HEATING AND VENTILATING UNIT
Schematic #S-9:

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	4@ $300. = $1,200.
	Differential pressure switch status indication	1@ $300. = $ 300.
		$1,500.

Savings:

Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.10 SYSTEM: CONVECTOR HEATING SYSTEM
Schematic #S-10

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Temperature Indication	1@ \$300. = \$300.
	Start/Stop interface with differential pressure switch status indication	1@ \$450. = \$450.
		\$750.

Savings:
Use ECUBE to simulate night setback operation. Assume a winter setback temperature reduction of 15°F.

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs:	Differential pressure switch status indicator	1@ \$300. = \$300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature Indication	3@ \$300. = \$ 900.
	Differential pressure switch status indication	1@ \$300. = \$ 300.
		\$1200.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.11 SYSTEM: HOT WATER CONVERTOR
Schematic #S-11

FUNCTION: O.A. SCHEDULE RESET, #14

Costs:	Temperature Indication	2@ \$300. = \$ 600.
	Controller Reset	1@ \$650. = \$ 650.
		\$1250.

Savings:

Savings are estimated in the same manner described for this function on schematic S-1. Because there are no flue losses, however, a decrease in annual energy consumption of 1% will be assumed.

$S = H \times 0.01 \times I$

Where

H = annual number of hours that convertor is activated

I = maximum heat transfer capacity of convertor, MBH

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs: Temperature Indication 2@ \$300. = \$600.

Savings:

Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.12 SYSTEM: TWO PIPE FAN COIL SYSTEM
Schematic #S-12

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with Differential Pressure Switch Status Indication 1@ $450. = $450.

Savings:
Simulate building loads and system operation using ECUBE in a manner similar to that used for this function on Schematic S-3. Instead of fan energy savings, calculate dual temperature pump savings.

Cooling Savings =
Difference in electrical consumption of ECUBE runs.

Heating Savings =
Difference in heating consumption of ECUBE runs.

Pump Savings =
HP x L x KW/HP x (8760 -H)
Where
HP = total pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
H = Number of hours of system operation

If the system is presently time switch started and stopped multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume the system may be shut down for an average of 15 minutes per hour. The savings resulting from this function are pump energy.

S = HP x L x 10/60 x H x KW/HP
Where
HP = total pump motor nameplate horsepower
15/60 = fraction of time system is shut down
H = required annual hours of system operation
L = 0.8 load factor
KW/HP = 0.746

SYSTEM: TWO PIPE FAN COIL SYSTEM
Schematic #S-12

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume system can be shed 25% of time under peak load conditions (same period as duty cycling).

S = HP x L x HP/KW x 0.25 x M
Where
HP = total pump motor nameplate horsepower
L = load factor, 0.8
HP/KW = 0.746
M = number of months per year system operates

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Space temperature indication	1@ $300. =	$300.
	Start/Stop interface with Differential pressure switch status indication	1@ $450. =	$450.
			$750.

Savings:
Use ECUBE to simulate thermostat setup/setback operation. Assume a summer setup of 5°F and a winter setback of 15°F.

FUNCTION: START/STOP OPTIMIZATION, #16

Cost: Same as SPACE NIGHT SETBACK = $750.

Savings:
Assume an average of 1/2 hour of pump operation per occupied day may be saved by this function. Assume no net heating or cooling energy is saved.

S = HP x L x KW/HP x 0.5 x OD
Where
HP = Total pump motor nameplate horsepower
L = load factor, use 0.8
KW/HP = 0.746
OD = number of occupied days per year

FUNCTION: MAINTENANCE RUN TIME REPORT, #23

Costs:	Differential pressure switch status indication	1@ $300. =	$300.

SYSTEM: TWO PIPE FAN COIL SYSTEM
Schematic #S-12

Savings:

Assume same as savings for this function on schematic S-1.

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	2@ $300. = $600.
	Differential pressure switch status indication	1@ $300. = $300.
		$900.

Savings:

Assume same as savings for this function on schematic S-1.

S = 2 man-hours

2.3.13 SYSTEM: STEAM UNIT HEATER SYSTEM
Schematic #S-13

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:

Start/Stop interface to open/close steam valve	1@ $450.	= $ 450.
Temperature Indication	1@ $300.	= $ 300.
New steam valve (based on 2-1/2" line)	1@ $500.	= $ 500.
		$1250.

Savings:

Simulate effect of night setback with ECUBE. Assume a total setback of 15°F. during unoccupied hours.

2.3.14 SYSTEM: STEAM BOILER
Schematic #S-14

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Pressure Indication	1@ \$500. = \$ 500.
	Alarm Contact Points	2@ \$250. = \$ 500.
		\$1000.

Savings:
Same as those calculated for this function on Schematic S-1:

S = 2 man-hours

FUNCTION: SAFETY ALARM, #26

Costs: Alarm contact point 1@ \$300. = \$300.

Savings:
Same as those calculated for this function on Schematic S-1:

S = 2 man-hours

2.3.15 SYSTEM: DIRECT FIRED FURNACE
Schematic #S-15

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs:	Start/Stop Interface with differential pressure switch status indication	1@ \$450. = \$450.

Savings:
Use same approach as that described for this function on Schematic #S-3. Include heating only in ECUBE analysis. If the system is presently time switch controlled, multiply the calculated savings by 0.3.

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Space temperature indication	1@ \$300. = \$300.
	Start/Stop interface with differential pressure switch status indication	1@ \$450. = \$450.
		\$750.

Savings:
Utilize ECUBE to simulate thermostat setup/setback operation. Assume a winter setback of 15°F.

FUNCTION: MAINTENANCE RUN TIME REPORT, #23

Costs:	Differential pressure switch status indication:	1@ \$300. = \$300.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Temperature indication	4@ \$300. = \$1200.
	Differential pressure switch status indication	1@ \$300. = \$ 300.
		\$1500.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.16 SYSTEM: DX UNIT, WATER COOLED
Schematic #S-16

FUNCTION: TIME SCHEDULED OPERATION, #1

Costs: Start/Stop Interface with Differential Pressure Switch 1@ $450. = $450.

Savings:

Assume electrical input to compressor and cooling tower fan is proportional to cooling load as described for this function on schematic S-2. Savings will result from condenser water pump shutdown:

$S = HP \times L \times KW/HP \times (8760-H)$

Where

HP = Condenser water pump motor horsepower

L = load factor, 0.8

KW/HP = 0.746

H = number of hours of system operation

If system is presently time clock controlled, multiply the above savings by 0.3.

FUNCTION: DUTY CYCLING, #2

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:

Savings will occur from condenser water pump shutdown:

$S = HP \times L \times KW/HP \times H \times 10/60$

Where

HP = condenser water pump motor horsepower

L = load factor, 0.8

KW/HP = 0.746

H = number of hours of system operation

FUNCTION: DEMAND LIMITING START/STOP, #3

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:

Savings similar to this function on schematic S-2 except for addition of condenser water pump horsepower.

SYSTEM: DX UNIT, WATER COOLED
Schematic #S-16

S = (HP1 + HP2 + HP3) x L x KW/HP x 0.25 x M
Where
HP1 = total compressor horsepower
HP2 = total cooling tower fan horsepower
HP3 = total condenser water pump horsepower
L = load factor, 0.8
KW/HP = 0.746
M = number of months per year system operates

FUNCTION: CONDENSER WATER RESET, #13

Costs:	Temperature indication	2@ $300.	= $ 600.
	Reset controller	1@ $650.	= $ 650.
	Differential pressure switch status	1@ $300.	= $ 300.
			$1550.

Savings:
Approximately 1.5% efficiency increase may be obtained by decreasing the average condenser water temperature 1°F. Assume the EMCS is capable of obtaining an average decrease of 3°F. in condenser water temperature, thus a resultant savings of 4.5% of compresser energy should be realized. To approximate these savings, assume a loading of 1000 equivalent full load hours. Also assume an average consumption of 1 KWH/ton-hour. Savings resulting are:

S = T x 1000 hrs. x 1 KWH/ton-hr x 0.045
Where
T = chiller capacity, tons

FUNCTION: START/STOP OPTIMIZATION, #16

Costs: Same as TIME SCHEDULED OPERATION = $450.

Savings:
Assume saving 1/2 hour of condenser water pump operation per day of operation:

S = HP x L x KW/HP x 0.5 x 0
Where
HP = pump motor horsepower
L = load factor, 0.8
KW/HP = 0.746
0 = days of operation

SYSTEM: DX UNIT, WATER COOLED
Schematic #S-16

FUNCTION: MAINTENANCE RUN TIME REPORTS, #23

Costs:	Differential pressure switch status	1@ $300. = $300.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs:	Differential pressure switch status	1@ $300. = $ 300.
	Temperature indication	2@ $300. = $ 600.
	Alarm contact points	4@ $250. = $1000.
		$1900.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

FUNCTION: SAFETY ALARMS, #26

Costs:	Alarm contact point	1@ $250. = $250.

Savings:
Same as this function on schematic S-1

S = 2 man-hours

2.3.17 SYSTEM: STEAM CONVECTOR HEATING SYSTEM
Schematic #S-17

FUNCTION: SPACE NIGHT SETBACK, #9

Costs:	Temperature Indication	1@ $300. =	$300.
	Control interruption interface	1@ $450. =	$450.
			$750.

Savings:
Use ECUBE to simulate night setback operation. Assume a winter setback temperature reduction of 15°F.

2.3.18 SYSTEM: HOT WATER CIRCUIT
Schematic #S-18

FUNCTION: SPACE NIGHT SETBACK, #9

Costs: Temperature Indication	1@ $300. =	$300.
Control Interrupt Interface	1@ $450. =	$450.
		$750.

Savings:
Utilize ECUBE to simulate night setback operation. Assume a winter setback temperature reduction of 15°F.

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs: Temperature Indication 3@ $300. = $ 900.

Savings:
Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.3.19 SYSTEM: HTW-TO-HW CONVERTOR
Schematic #S-19

FUNCTION: O.A. SCHEDULE RESET, #14

Costs: Temperature Indication	1@ $300. =	$ 300.
Controller Reset	1@ $650. =	$ 650.
		$ 950.

Savings:

Savings are estimated in the same manner described for this function on schematic S-1. Since there are no flue losses, however, a decrease in annual energy consumption of 1% will be assumed.

$S = H \times 0.01 \times I$

Where

H = annual number of hours that convertor is activated

I = maximum heat transfer capacity of convertor, MBH

FUNCTION: TROUBLE DIAGNOSIS, #24

Costs: Temperature Indication 2@ $300. = $600.

Savings:

Assume same as savings for this function on schematic S-1:

S = 2 man-hours

2.4 SURVEY AND CALCULATION FORMS

SURVEY AND CALCULATION FORM

System Schematic: S-1; Hot Water Boiler

Building Number: ____________________ Building System: ____________________

Operation Schedule: ____________________ Fuel: ____________________

Peak Output Capacity: ____________ MBH Input at Peak Output: ____________ MBH

H.W. Pump HP: ____________ HP Annual Hours of Operation: ____________________

Controls: ____

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #14, O.A.Schedule Reset	$_____	_____	_____	_____	_____
____________________________					
___ #23, Maint. Run Time Reports	$_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	$_____	_____	_____	_____	_____
___ #26, Safety Alarms	$_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-2, DX Unit, Air Cooled

Building Number:________________ Building System:________________

Total System Capacity: ______________________________ Tons

Total Compressor Motor Nameplate HP: ______________________ HP

Total Condenser Fan Motor Nameplate HP: ____________________ HP

Operation Schedule: ______________________________

Controls: ______________________________

NOTES: ______________________________

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	$_____	_____	_____	_____	_____
___ #2, Duty Cycling	$_____	_____	_____	_____	_____
___ #3, Demand Limiting Start/Stop	$_____	_____	_____	_____	_____
___________________					
___ #16, Start/Stop Optimization	$_____	_____	_____	_____	_____
___ #23, Maint. Run Time Reports	$_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	$_____	_____	_____	_____	_____
___ #26, Safety Alarms	$_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-3, Single Zone Air Handler

Building Number: ____________________ Building System: ____________________

Supply CFM: __________ Supply Fan HP: __________ Return Fan HP: __________

Economizer Status: ____

Min. O.A. CFM: ____________________ Time Clock Control: __________

Occupancy Schedule: ____

Critical Areas/Equipment: ____

Controls: ____

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	$_____	_____	_____	_____	_____
___ #2, Duty Cycling	$_____	_____	_____	_____	_____
___ #3, Demand Limiting Start/Stop	$_____	_____	_____	_____	_____
___ #8, Enthalpy Economizer	$_____	_____	_____	_____	_____
___ #9, Space Night Setback	$_____	_____	_____	_____	_____
___ #16, Start/Stop Optimization	$_____	_____	_____	_____	_____
___ #23, Maint. Run Time Reports	$_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	$_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-4, Terminal Reheat Air Handler

Building Number: ____________________ Building System: ____________________

Occupancy Schedule: ____________________ No. Reheat Zones: ____________________

Supply CFM: __________ Supply Fan HP: __________ Return Fan HP: __________

Min. O.A. CFM: ____________________ Time Clock Control: ____________________

Economizer Status: ____________________ Design Cooling Coil LVG Temp: __________

Cooling Coil Capacity: __________ MBH Total Reheat Coil Capacity: __________MBH

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	$_____	_____	_____	_____	_____
____________________________					
___ #2, Duty Cycling	$_____	_____	_____	_____	_____
____________________________					
___ #3, Demand Limiting Start/Stop	$_____	_____	_____	_____	_____
____________________________					
___ #8, Enthalpy Economizer	$_____	_____	_____	_____	_____
____________________________					
___ #9, Space Night Set Back	$_____	_____	_____	_____	_____
____________________________					
___ #11, Reheat Coil Reset	$_____	_____	_____	_____	_____
____________________________					
___ #16, Start/Stop Optimization	$_____	_____	_____	_____	_____
____________________________					
___ #23, Maint. Run Time Reports	$_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	$_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-5; Chiller - Air Cooled

Building Number:____________________ Building System:____________________

Total System Capacity: ____ Tons

Total Compressor Motor Nameplate HP: ______________________________ HP

Total Condenser Fan Motor Nameplate HP: ____________________________ HP

Chilled Water Pump HP: ____ HP

Operation Schedule: ____

Existing Time Clock Control: ____________________________________

Controls: ____

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operations ______________________	$_____	_____	_____	_____	_____
___ #2, Duty Cycling ______________________	$_____	_____	_____	_____	_____
___ #3, Demand Limiting Start/Stop ______________________	$_____	_____	_____	_____	_____
___ #12, Chilled Water Reset ______________________	$_____	_____	_____	_____	_____
___ #16, Start/Stop Optimization ______________________	$_____	_____	_____	_____	_____
___ #23, Maint. Run Time Reports	$_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	$_____	_____	_____	_____	_____
___ #26, Safety Alarms	$_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-6, Multizone Air Handler

Building Number: ____________ Building System: ____________

Occupancy Schedule: ____________

Number Zones: ____________

Supply CFM: ________ Supply Fan HP: ________ Return Fan HP: ________

Min. O.A. CFM: ____________ Time Clock Control: ____________

Cooling Coil Capacity: ________ MBH, Design Cooling Coil LVG. Temp: ________

Heating Coil Capacity: ________ MBH, Design Heating Coil LVG. Temp: ________

NOTES: ____________

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___	___
___ #2, Duty Cycling	___	___	___	___	___
___ #3, Demand Limiting Start/Stop	___	___	___	___	___
___ #8, Enthalpy Economizer	___	___	___	___	___
___ #9, Space Night Setback	___	___	___	___	___
___ #10, Hot/Cold Deck Reset	___	___	___	___	___
___ #16, Start/Stop Optimization	___	___	___	___	___
___ #23, Maint. Run Time Reports	___	___	___	___	___
___ #24, Trouble Designosis	___	___	___	___	___

SURVEY AND CALCULATION FORM

System Schematic: S-7, Single Zone Split System

Building Number: ____________________ Building System: ____________________

Supply CFM: ____________ Supply Fan HP: ____________ Return Fan HP: ____________

Economizer Status : ____

Min. O.A. CFM: ________________ Time Clock Control: ________________

Total Compressor HP: ________________ Total Condenser Fan HP: ____________

Occupancy Schedule: ____

Critical Areas/Equipment: ____

Controls: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	_____	_____	_____	_____	_____
___ #2, Duty Cycling	_____	_____	_____	_____	_____
___ #3, Demand Limiting Start/Stop	_____	_____	_____	_____	_____
___ #8, Enthalpy Economizer	_____	_____	_____	_____	_____
___ #9, Space Night Setback	_____	_____	_____	_____	_____
___ #16, Start/Stop Optimization	_____	_____	_____	_____	_____
___ #23, Maint. Run Time Reports	_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-8, Chiller - Water Cooled

Building Number: ____________________ Building System: ____________________

Total System Capacity: ____________________ Tons, Time Clock Control: ____________

Total Compressor Motor Nameplate HP: ____________________ HP

Total Cooling Tower Fan Motor Nameplate HP: ____________________ HP

Chiller Water Pump HP: ____________ HP, Condenser Water Pump HP: ____________ HP

Operation Schedule: ____

Controls: ____

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	_____	_____	_____	_____	_____
___ #2, Duty Cycling	_____	_____	_____	_____	_____
___ #3, Demand Limiting Start/Stop	_____	_____	_____	_____	_____
___ #12, Chilled Water Reset	_____	_____	_____	_____	_____
___ #13, Cond. Water Reset	_____	_____	_____	_____	_____
___ #16, Start/Stop Optimization	_____	_____	_____	_____	_____
___ #23, Maint. Run Time Reports	_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____
___ #26, Safety Alarms	_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-9, Heating & Ventilating Unit

Building Number: ____________________ Building System: ____________________

Supply CFM: ____________ Supply Fan HP: ________ Return Fan HP: ________

Min. O.A. CFM: ______________ Time Clock Control: ____________________

Occupancy Schedule: ____

Critical Areas/Equipment: ____

Controls: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___	___
___ #2, Duty Cycling	___	___	___	___	___
___ #3, Demand Limiting Start/Stop	___	___	___	___	___
___ #9, Space Night Setback	___	___	___	___	___
___ #16, Start/Stop Optimization	___	___	___	___	___
___ #23, Maint. Run Tim Reports	___	___	___	___	___
___ #24, Trouble Diagnosis	___	___	___	___	___

SURVEY AND CACLULATION FORM

System Schematic: S-10, Convector Heating System

Building Number: ____________ Building System: ____________

Zone Heating Pump HP: ________ Total Heating Capacity ________ MB

Occupancy Schedule: ____________

Controls: ____________

NOTES: ____________

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #9, Space Night Setback	___	___	___	___	___
____________					
___ #23, Maint. Run Time Reports	___	___	___	___	___
___ #24, Trouble Diagnosis	___	___	___	___	___

SURVEY AND CALCULATION FORM

System Schematic: S-11, Hot Water Convertor

Building Number: ____________ Building System: ____________

Annual Hours of Convertor Operation: ________ Original Fuel Source: ________

Maximum Heat Trans. Capacity: ______________________ MBH

Operation Schedule: ______________________

Controls: ______________________

NOTES: ______________________

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #14, O.A. Schedule Reset	___	___	___	___	___
______________________					
___ #24, Trouble Diagnosis	___	___	___	___	___

SYSTEM/FUNCTION/SAVINGS ANALYSIS

System Schematic: S-12, Two Pipe Fan Coil Systems

Building Number: ____________________ Building System: ____________________

Dual Temperature Pump HP: ____________ HP Time Clock Control: ____________

Operation Schedule: ____

Controls: ____

NOTES: ____

EMCS Function	Tot. $	KW	KWH	THERMS	MH
___ #1, Time Schedule Operation	____	____	____	____	____
____________________					
___ #2, Duty Cycling	____	____	____	____	____
____________________					
___ #3, Demand Limiting Start/Stop	____	____	____	____	____
____________________					
___ #9, Space Night Setback	____	____	____	____	____
____________________					
___ #16, Start/Stop Optimization	____	____	____	____	____
____________________					
___ #23, Maint. Run Time Reports	____	____	____	____	____
___ #24, Trouble Diagnosis	____	____	____	____	____

SURVEY AND CALCULATION FORM

System Schematic: S-13, Steam Unit Heater System

Building Number:____________________ Building System:____________________

Total Unit Heater Capacity: ____ MBH

Occupancy Schedule: ____

Occupied Hours of Operation: ____

Occupied Temperature: __________ F Unoccupied Temperature __________ F

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #9, Space Night Setback	_____	_____	_____	_____	_____
____________________________					

SURVEY AND CALCULATION FORM

System Schematic: S-14, Steam Boiler

Building Number: ____________________ Building System: ____________________

Fuel: ____

Peak Output Capacity: __________ MBH Input at Peak Output: __________ MBH

Operation Schedule: ____

Controls: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____
___ #26, Safety Alarm	_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-15, Direct Fired Furnace

Building Number: ____________________ Building System: ____________________

Supply CFM: __________ Supply Fan HP: __________ Return Fan HP: __________

Min. O.A. CFM: ____________________ Time Clock Control: ____________________

Peak Output Capacity MBH: ________ MBH Input at Peak Output: ________ MBH

Occupancy Schedule: ____

Hours of Operation: ____

Critical Areas/Equipment: ____

Controls: ____

NOTES: ____

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
___ #1, Time Schedule Operation	_____	_____	_____	_____	_____
____________________					
___ #9, Space Night Setback	_____	_____	_____	_____	_____
____________________					
___ #23, Maint. Run Time Reports	_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-16; DX Unit, Water Cooled

Building Number: ______________________ Building System: ______________________

Total System Capacity: ____________ Tons; Time Clock Control: ____________

Total Compressor Motor Nameplate HP: ______________________________ HP

Total Cooling Tower Fan Motor Nameplate HP: ______________________________ HP

Condenser Water Pump HP: ______________________________ HP

Occupancy Schedule: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___	___
______________________					
___ #2, Duty Cycling	___	___	___	___	___
______________________					
___ #3, Demand Limiting Start/Stop	___	___	___	___	___
______________________					
___ #13, Cond. Water Reset	___	___	___	___	___
______________________					
___ #16, Start/Stop Optimization	___	___	___	___	___
______________________					
___ #23, Maint. Run Time Reports	___	___	___	___	___
___ #24, Trouble Diagnosis	___	___	___	___	___
___ #26, Safety Alarms	___	___	___	___	___

SURVEY AND CALCULATION FORM

System Schematic: S-17, Steam Converter Heating System

Building Number: ____________________ Building System: ____________________

Total Heating Capacity: ____ MBH

Operation Schedule: ____

Occupied Hours: ____

Controls: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #9, Night Setback	______	______	______	______	______
____________________________					

SURVEY AND CALCULATION FORM

System Schematic: S-18, Hot Water Circuit

Building Number:________________ Building System:________________

Total Heating Capacity: ________________________________ MBH

Occupancy Schedule: ________________________________

Controls:________________________________

NOTES: ________________________________

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #9, Space Night Setback	_____	_____	_____	_____	_____
________________________					
___ #23, Maint. Run Time Reports	_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____

SURVEY AND CALCULATION FORM

System Schematic: S-19, HTW-TO-HW Converter

Building Number: ____________________ Building System: ____________________

Annual Hours of Convertor Operation: ________ Original Fuel Source: __________

Maximum Heat Trans. Capacity: ____ MBH

Operation Schedule: ____

Controls: ____

NOTES: ____

EMCS Function	Savings				
	Tot. $	KW	KWH	THERMS	MH
___ #14, O.A. Schedule Reset	_____	_____	_____	_____	_____
___ #24, Trouble Diagnosis	_____	_____	_____	_____	_____

3.0 DESIGN ANALYSIS PROCEDURE: STEP BY STEP EXAMPLES

3.1 INTRODUCTION

The purpose of Section 3 of the AIR FORCE EMCS APPLICATION STUDY is to provide a step by step guide for use of the analysis procedure developed as a part of this study. Explanation of the reasoning behind the process described in this section is contained in Sections 1 and 2 of this report. Some of these steps have been computerized, in addition to the manual approach described here. These steps are noted and the documentation on the use of these programs, along with example problem and program listings, are included in Volume II of this report.

In order to provide step by step instructions in the use of the EMCS analysis procedure, each major step in the process is described in a section in this volume. Along with the step by step description, the application of each of those steps to a hypothetical Air Force Base is included in each section.

This procedure has been prepared for use by professional engineering personnel. It is not possible to describe completely all activities involved in an engineering design process. For this reason, this section is meant only to be used as a framework for EMCS analysis. Every military base is different, and parts of the process described herein must be adapted, added to, or ignored as the situation requires. The judgement required to make these decisions requires a mechanical and electrical engineering design team fully familiar with the mechanical and electrical systems an EMCS is to control and how that control is to be accomplished.

3.2 METHODOLOGY OVERVIEW

The steps described in this volume have a single purpose. That is to determine the best EMCS configuration for a particular Air Force Base. To accomplish this, the following major steps are required:

1. Scope Determination
2. Field Investigation
3. Analysis Preliminaries
4. Savings Estimation
5. Cost Estimate/Ranking Process
6. Transmission System Configuration
7. Central System Configuration
8. Prioritization Analysis
9. Final EMCS Configuration

Scope Determination consists of the gathering of initial data on the proposed EMCS project. The primary result of this effort is a list of buildings and facilities to be considered for EMCS connection which must be visited during the field investigation.

Field Investigation is visiting the site to determine what systems are present in the buildings being considered for EMCS connection. The operation of each system and the building it serves must be determined in sufficient detail to determine which EMCS functions may be applicable to each system.

Analysis Preliminaries include preparatory activities necessary to perform the savings and cost analysis on each system/function considered for EMCS connection. These activities include gathering of unit cost estimating data to be used, determining and summarizing the procedure to be used in savings analysis of each system/function, determining current unit energy costs, preparing or adapting schematics for systems found during field investigation, etc.

The Savings Estimation effort is the system by system selection of applicable EMCS functions and the estimation of savings which would result from the application of each of those functions.

The Cost Estimate/Ranking Process is the system by system analysis whereby each function is economically ranked according to its payback period while taking into account the "field hardware duplicity" concept described in Section 1.5 of this report.

Transmission System Configuration is the conceptual design of the EMCS data transmission network and the estimation of the costs associated with each element of that network.

Central System Configuration is the conceptual design of the central EMCS equipment and software and its cost estimation. In addition, related items such as EMCS operator costs, maintenance costs, and training costs are included in the investigation of this area.

The Prioritization Analysis is the final ranking of EMCS system functions on a base-wide basis. This analysis takes into account the "geography cost" aspects of the EMCS data transmission network as described in Section 1.5 of this report. The end result of the Prioritization Analysis is a list of all system/functions considered for EMCS connection in order, from best to worst, based on providing the most savings for the least investment.

The Final EMCS Configuration process uses the results of the prioritization analysis to accomplish one of two possible purposes. One

possible purpose is the determination of an appropriate EMCS budget for the Air Force Base being analyzed. The other possible purpose is determination of the best EMCS configuration for a base with an established budget. In either case, a final proposed list of the systems to be connected to the EMCS, the functions to be performed on those systems, and the EMCS field sensors/controllers required to perform those functions must be prepared. This list is then used in the final EMCS contract document preparation process where it must be fully field verified.

3.3 EXAMPLE PROBLEM DESCRIPTION

To illustrate the step by step EMCS analysis description included in this volume, an example of the application of each step has been included. Instead of independent isolated examples, the approach taken has been to perform the complete analysis on a single example problem. The example problem chosen is a hypothetical five building Air Force Base. The five buildings and the systems serving those buildings have been chosen as typical of the type found on many Air Force Bases. This approach for a step by step explanation was chosen so that the principles of each step can be clearly explained and illustrated without being confused by the complexity and sheer volume of an analysis of an actual Air Force Base (from 10 to 100 times the complexity of this simple five building example).

The buildings which comprise the hypothetical Air Force Base (call it John Doe Air Force Base) and the systems within each building are listed below:

BUILDING NUMBER:	100
USAGE:	BASE CIVIL ENGINEERING
SYSTEMS:	Hot Water Boiler
	Air Cooled Chiller
	Multizone Air Handler
BUILDING NUMBER:	200
USAGE:	SQUADRON OPERATIONS
SYSTEMS:	Steam Boiler
	Single Zone Split System
BUILDING NUMBER:	300
USAGE:	BASE HEADQUARTERS
SYSTEMS:	2 Hot Water Boilers
	Air Cooled Chiller
	Single Zone Air Handler
	2 Multizone Air Handlers

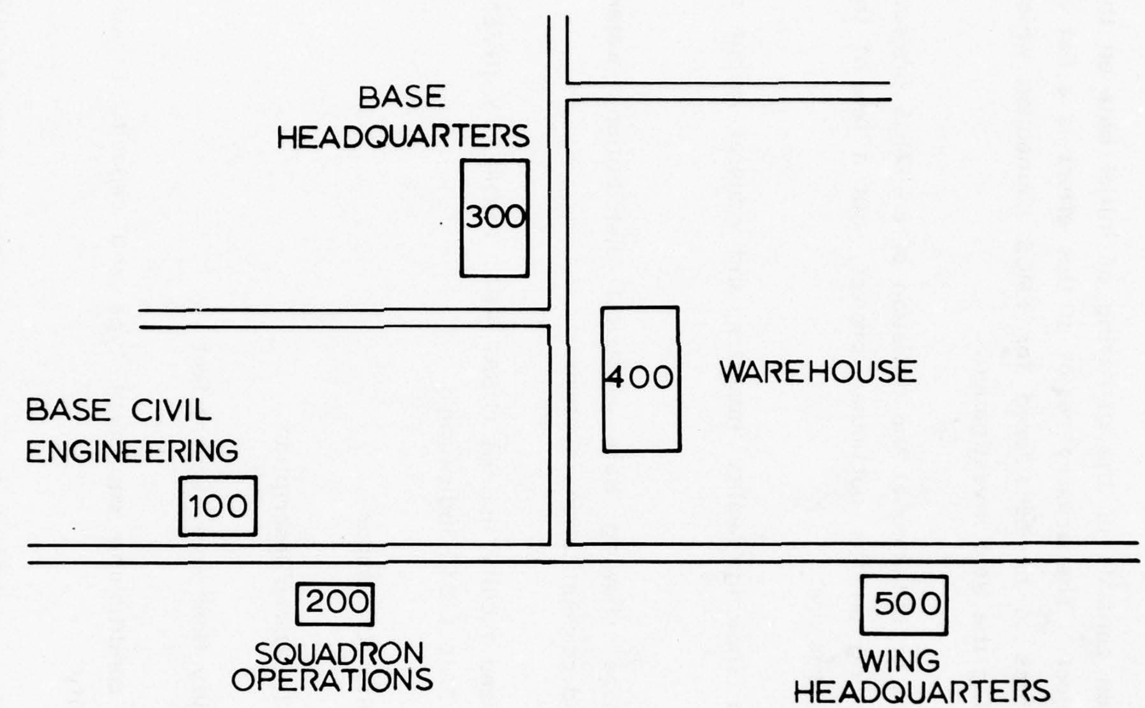
BUILDING NUMBER:	400
USAGE:	WAREHOUSE
SYSTEMS:	Steam Unit Heater System
	Steam Boiler

BUILDING NUMBER:	500
USAGE:	WING HEADQUARTERS
SYSTEMS:	Hot Water Boiler
	Single Zone Split System

A map of John Doe Air Force Base is included on Figure 4.

Criteria for this example analysis will be assumed to require contractor furnished data transmission cable. This approach is taken to illustrate the analysis technique. If the data transmission system is assumed to be government furnished telephone lines, the analysis is considerably simplified, however, this would not fully demonstrate the analysis principles being used.

Another criterion used will be the assumption that the purpose of the EMCS is to provide monetary savings through control of energy consuming equipment. This is consistent with current policy. Performing the analysis to optimize energy savings is very simple if that were given as the desired end. That approach only requires the changing of conversion constants from $/KWH and $/THERM to BTU/KWH and BTU/THERM. Since dollar savings is the current primary criterion, that approach will be used in the example problem.



JOHN DOE AIR FORCE BASE

3.4 SCOPE DETERMINATION

Scope Determination consists of the gathering of initial data on the proposed EMCS project. The primary result of this effort is a list of buildings and facilities to be considered for EMCS connection which must be visited during the field investigation.

Several items must be obtained at the initiation of an EMCS project. These vary, depending on the particular project, but a few of the normally requested items are:

1. Base map showing facility numbers and general layout of Base.

2. Utility maps showing Base electrical distribution, water, sewer, and communications systems.

3. Computerized facility listings (USAF REAL PROPERTY INVENTORY DETAIL LIST) indicating:

    a. Facility ID Number

    b. Facility Name/Description

    c. Facility floor area, square feet

    d. Air conditioning equipment type and capacity in each facility

    e. Heating equipment type and capacity in each facility.

    f. Other energy consuming equipment type and size (compressors, etc.) in each facility

4. Utility cost data including rate structures or current prices, and copies of billings over the last year. Estimated local escalation rates should be provided if available.

5. Information from the Base Communications Office on the quality, availability, and cost of utilizing Base telephone lines for data transmission.

6. Shop drawings, specifications, or other information on any existing EMCS or similar central control systems.

7. Information on any past, current, or future energy conservation projects such as control upgrades, insulation projects, etc.

8. Plans for future additions to buildings or new buildings which might be connected to or affect the EMCS. Also, plans for demolition of existing buildings.

9. Listings of critical facilities which should be connected to the EMCS for monitoring purposes (computer rooms, flight simulators, etc.).

After the initial data are obtained, the buildings to be considered for EMCS connection may be determined. This selection may be based on sizes of building, air conditioning tonnage, heating system capacity, or any other criteria related to energy consumption. Base engineering personnel must be closely involved in this process because they may know facts not included on Base maps or computer printouts which are relevant to whether or not a building should be considered for EMCS connection.

3.4.1 SUMMARY OF STEPS:

1. Obtain data items listed in 3.4.

2. Set selection criteria (building area, air conditioning tonnage, etc.).

3. Produce initial list of buildings to consider.

4. Coordinate and check initial list with Base Civil Engineering personnel.

5. Produce final list of buildings to consider.

3.4.2 EXAMPLE:

Because John Doe Air Force Base is a hypothetical case, the requirements of scope determination are satisfied by default. An example of a common computerized facility list is included as Figure 5 for reference purposes. The final building list for John Doe Air Force Base is included as Figure 6.

PREPARED 77 APR 26 22106 USAF REAL PROPERY INVENTORY DETAIL LIST AS OF 77 APR 26 PCN N200180

INSTALLATION HOMESTEAD AFB CMD TAC

FAC NR	I N	T C	C D	C C	CM CD	A D	BH RD	CATEGORY CODE	CATEGORY DESCRIPTION	AREA VACANT	AREA OUT-NLS	AREA OUT-LS	AREA TOTAL	UM	OTHER AMOUNT	UM	RENT PAID	RENT RECD	COST TO GOVT	EST VALUE	YR CM
00670	1	P	1	X	52			826122	A/C PLT 25-100 TN		50				50	TN			6		65
00672	1	P	1	A	52			721312	DORM AM PP/PCS-STD		25245		25245	SF	116	MN			373		65
00672	1	P	1	X	52			826122	A/C PLT 25-100 TN		50				50	TN			6		65
00674	1	P	1	A	52			610811	ADMIN OFCP NON-AF		10688		10688	SF					371		56
00674	1	P	1	X	52			821116	HTG PLT OV 3500 MB		5				5222	MB			13		56
00674	1	P	1	X	52			826122	A/C PLT 25-100 TN		50				50	TN			6		56
00674	1	P	1	X	52			890126	A/C WINDOW UNITS		2		252	SF	2	TN			1		76
00675	1	P	2	A	OT			721312	DORM AM PP/PCS-STD				25364	SF	152	MN			254		56
00675	1	P	1	X	OT			826122	A/C PLT 25-100 TN						50	TN			70		69
00675	1	P	1	X	OT			880221	AUTO FP DTECTN SYS				25364	SF	96	EA			7		74
00676	1	P	2	A	OT			721312	DORM AM PP/PCS-STD				25364	SF	152	MN			232		56
00676	1	P	1	X	OT			826122	A/C PLT 25-100 TN						50	TN			3		56
00676	1	P	1	X	OT			880221	AUTO FR DTECTN SYS				25364	SF	96	EA			7		74
00676	1	P	1	X	OT			890126	A/C WINDOW UNITS				598	SF	3	TN			2		76
00679	1	P	1	A	OT			610122	BSE SUP ADMIN				4032	SF					56		55
00679	1	P	1	X	OT			890121	A/C PLT 5 TO 25 TN						15	TN			15		71
00681	1	P	1	A	OT			610711	PLTP DATA PROCESS				4608	SF					165		55
00681	1	P	1	X	OT			826122	A/C PLT 25-100 TN						27	TN			52		69
00681	1	P	1	X	OT			890121	A/C PLT 5 TO 25 TN						10	TN			12		76
00682	1	P	1	A	OT			811149	ELEC PWR STN BLDG				320	SF					10		72
00686	1	P	2	B				540243	DEN CLINIC				8255	SF	12	DU			328		59
00686	1	P	2	D	OT			540243	DEN CLINIC				7735	SF	12	DU					59
00686	1	P	2	D	OT			540244	DEN SURG & RECOVY				520	SF							59
00686	1	P	1	X	OT			826122	A/C PLT 25-100 TN						45	TN			4		59
00698	1	P	1	E	OT			890187	UTIL VAULT				72	SF					17		69
00699	1	P	1	A	OT			811149	ELEC PWR STN BLDG				444	SF					48		70
00699	1	P	1	X	OT			811147	ELEC E/PWR GEN PLT						300	KW			28		69
00700	1	P	1	A	OT			219947	BE STOR SHED				44	SF					2		59
00701	1	P	1	B				610249	HQ WG				22407	SF					560		59

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FIGURE 5 - A COMMON COMPUTERIZED FACILITY LIST

JOHN DOE BUILDING LIST CONSIDERED FOR EMCS

Bldg #	Building Name	Area	Tons	MBH
100	BASE CIVIL ENGINEERING	14000	40	750
200	SQUADRON OPERATIONS	7000	20	500
300	BASE HEADQUARTERS	51000	160	3000
400	WAREHOUSE	70000	-	3000
500	WING HEADQUARTERS	13000	40	600

FIGURE 6 - FINAL BUILDING LIST FOR JOHN DOE A.F.B.

3.5 FIELD INVESTIGATION

Field Investigation is visiting the site to determine what systems are present in the buildings being considered for EMCS connection. The operation of each system and the building it serves must be determined in sufficient detail to determine which EMCS functions may be applicable to each system.

Once the scope determination phase has produced a list of the buildings to be investigated, additional information must be obtained before actual building by building surveying begins. The desired data consist of:

1. "As-built" mechanical, electrical and control drawings of each building being considered for connection to the EMCS.

2. Schedules of occupancy and usage for people, lights, and equipment for each building.

3. Any available small scale plans of buildings on the list for consideration.

The "as-built" mechanical drawings are a necessity for the efficient use of field survey time. Without them, much time may be wasted in trying to track down every mechanical room in a building, particularly if the building is large and has been extensively remodeled. Because of the large number of systems and drawings on a military base, obtaining the required prints can be a problem. In general, if base personnel are simply asked to provide copies of all mechanical and electrical drawings for the buildings on the list, difficulties occur. Fulfilling such a request will require 500 to 2000 prints. Base Civil Engineering records departments are not usually equipped to handle such a load in the time frame needed. Also, many of the drawings which would be provided by such a request are not needed for the EMCS design analysis. The best solution to this problem is for the EMCS design engineer to review the tracing files for the buildings in

question. Only those tracings which are absolutely necessary for use in the EMCS field investigation should be selected for printing. Whatever approach is to be utilized, it must be clearly defined before the project is initiated and dates established by which drawings must be provided.

To perform detailed analysis of a proposed EMCS, schedules of occupancy and usage for people and equipment in the buildings being considered must be obtained. On some bases this information has been gathered for use in other projects and may be available through the Base Civil Engineering Office. If not, it must be obtained. Several approaches may be used, including a telephone survey of custodians of each building, written memos to the users of each building, discussion with base maintenance personnel, or visits to each building to discuss schedules with the occupants.

On some bases, small scale plans of buildings may be available. These have usually been prepared for use in planning, office allocations, fire escape routes, or other purposes. These drawings are generally on 8-1/2" x 11" sheets at whatever scale is necessary to depict floor plans of the building. These drawings are extremely useful in the building by building survey for the identification and location of systems. If these are not available, full scale drawings are not as convenient for the field investigation but they can be used.

Once drawings are obtained, they are used to plan the survey work to be done during each site visit. Much time can be wasted without a definite plan of items to be accomplished during each day of the field investigation and adequate preparations to meet planned requirements.

The purpose of the field investigation is to determine which systems are to be considered for EMCS connection and to gather enough information on each system to allow analysis of that system. Once the design analysis is completed and the systems to be connected to the EMCS are identified, a detailed field inspection of each of those systems must be performed in the final design stage. This detailed survey must closely

examine each system for sensor location, existing controls condition, EMCS interface to local controls, damper actions, etc. However, the field investigation required to perform the basic design analysis described in this report does not require this detailed hardware inspection. The field work for the design analysis stage of the project is primarily concerned with identifying the type of system in question, its current operating hours, its required operating hours, the horsepowers of motors in the system, and other data required for the analysis of savings which would result from EMCS control of that system.

The most efficient approach to the field investigation itself has been found to be the gathering of as much data as possible from drawings of each building and using the site survey to verify the data obtained from the drawings. One important aspect of this approach is the development of standard survey data sheets. These sheets provide a basis for the data gathering and should include blanks for all data pertinent to the analysis. The data sheets developed during this study include a master sheet for each building and additional sheets for each system within that building. The additional sheets are specially adapted for each system type and examples are included for each system in Section 2 of this report. The system data sheets also contain space to calculate savings resulting from that system, once all the data have been gathered. Each engineer has a different approach to the survey data recording problem and whether one uses a separate form for each system type, a single standard form, a tabular approach, or some other method is not important as long as the data are recorded and easily referred to.

3.5.1 SUMMARY OF STEPS:

1. Obtain needed "as built" mechanical and electrical drawings of buildings to be investigated.

2. Obtain schedules of occupancy and usage for each building.

3. Obtain small scale floor plans of each building, if available.

4. Plan field work.

5. Obtain as much information as possible from drawings before site visits.

6. Make site survey to confirm data shown on drawings, locate systems for which drawings are unavailable, and gather additional data required for the analysis of EMCS savings for each system.

7. Compile site survey data in common format for use in subsequent calculations and analysis.

3.5.2 EXAMPLE:

John Q. Engineer at John Doe Air Force Base was quite helpful in obtaining the information required for the field investigation. The survey data forms for the five buildings being considered for EMCS connection are included as Figures 7 through 21.

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-1, Hot Water Boiler

Building System: 1

Operation Schedule: 730-1630 M-F Fuel: #2 Oil

Peak Output Capacity: 750 MBH Input at Peak Output: 1000 MBH

H.W. Pump HP: 3/4 HP Annual Hours of Operation: 24 HRS, OCT-APRIL = 5040 HRS/YR

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
____ #14, O.A.Schedule Reset					
____ #23, Maint. Run Time Reports					
____ #24, Trouble Diagnosis					
____ #26, Safety Alarms					

FIGURE 7 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-5, Chiller - Air Cooled

Building System: 2

Total System Capacity: 40 Tons

Total Compressor Motor Nameplate HP: 40 HP

Total Condenser Fan Motor Nameplate HP: 5 HP

Chilled Water Pump HP: 3 HP

Operation Schedule: 2346 HRS./YR.

Existing Time Clock Control: NO

Controls:

NOTES: DISCONNECTED FROM OCT. 30 TO April 1 $8760 \times 6/12 = 4380$ Hrs./YR. $2346 \times 6/12 = 1173$ Hrs./YR.

EMCS Function	Savings KW	KWH	THERMS	MH
____ #1, Time Scheduled Operations				
____ #2, Duty Cycling				
____ #3, Demand Limiting Start/Stop				
____ #12, Chilled Water Reset				
____ #16, Start/Stop Optimization				
____ #23, Maint. Run Time Reports				
____ #24, Trouble Diagnosis				
____ #26, Safety Alarms				

FIGURE 8 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-6, Multizone Air Handler

Building System: 3 Occupancy Schedule: 730 – 1630 M-F

Number Zones: 5

Supply CFM: 16000 Supply Fan HP: 15 Return Fan HP: 0

Min. O.A. CFM: 16000 Time Clock Control: NO

Cooling Coil Capacity: 480 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 300 MBH, Design Heating Coil LVG. Temp: 85

NOTES: BOILER OR CHILLER SHUT OFF WHEN OTHER ON, AIR UNIT OPERATES LIKE SINGLE ZONE UNIT.

EMCS Function	Savings KW	KWH	THERMS	MH
____ #1, Time Scheduled Operation	____	____	____	____
____ #2, Duty Cycling	____	____	____	____
____ #3, Demand Limiting Start/Stop	____	____	____	____
____ #8, Enthalpy Economizer	____	____	____	____
____ #9, Space Night Setback	____	____	____	____
____ #10, Hot/Cold Deck Reset	____	____	____	____
____ #16, Start/Stop Optimization	____	____	____	____
____ #23, Maint. Run Time Reports #24, Trouble Diagnosis	____	____	____	____

FIGURE 9 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 200 System Schematic: S-14, Steam Boiler

Building System: 1

Fuel: #2 OIL

Peak Output Capacity: 500 MBH Input at Peak Output: 650 MBH

Operation Schedule: OCTOBER THRU MAY

Controls: ____

NOTES: ____

EMCS Function	Savings KW	KWH	THERMS	MH
____ #23, Trouble Diagnosis				
____ #26, Safety Alarm				

FIGURE 10 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 200 System Schematic: S-7, Single Zone Split System

Building System: 2

Supply CFM: 8000 Supply Fan HP: 5 Return Fan HP: 0

Economizer Status : COULD BE USED FOR ENTHALPY CONTROL

Min. O.A. CFM: 1200 Time Clock Control: YES

Total Compressor HP: 20 Total Condenser Fan HP: 2

Occupancy Schedule: 730 – 1630 M-F = 2346 HRS./YR.

Critical Areas/Equipments: NONE

Controls: ____

NOTES: ____

EMCS Function	Savings KW	KWH	THERMS	MH
____ #1, Time Scheduled Operation				
____ #2, Duty Cycling				
____ #3, Demand Limiting Start/Stop				
____ #8, Enthalpy Economizer				
____ #9, Space Night Setback				
____ #16, Start/Stop Optimization				
____ #23, Maint. Run Time Reports				
____ #24, Trouble Diagnosis				

FIGURE II - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-1, Hot Water Boiler

Building System: 1

Operation Schedule: 730-1630 M-F Fuel: #2 OIL

Peak Output Capacity: 1500 MBH Input at Peak Output: 2000 MBH

H.W. Pump HP: 5 HP Annual Hours of Operation: 5040

Controls: ____

NOTES: ____

EMCS Function	Savings KW	KWH	THERMS	MH
____ #14, O.A. Schedule Reset	____	____	____	____
____				
____				
____				
____ #23, Maint. Run Time Reports	____	____	____	____
____ #24, Trouble Diagnosis	____	____	____	____
____ #26, Safety Alarms	____	____	____	____

FIGURE 12 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-1, Hot Water Boiler

Building System: 2

Operation Schedule: 730-1630 M-F Fuel: #2 OIL

Peak Output Capacity: 1500 MBH Input at Peak Output: 2000 MBH

H.W. Pump HP: 5 HP Annual Hours of Operation: 8760

Controls: ______

NOTES: ______

EMCS Function	KW	KWH	THERMS	MH
____ #14, O.A. Schedule Reset	____	____	____	____
______				
______				
______				
____ #23, Maint. Run Time Reports	____	____	____	____
____ #24, Trouble Diagnosis	____	____	____	____
____ #26, Safety Alarms	____	____	____	____

(Savings columns: KW, KWH, THERMS, MH)

FIGURE 13 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-5, Chiller - Air Cooled

Building System: 3

Total System Capacity: 160 Tons

Total Compressor Motor Nameplate HP: 200 HP

Total Condenser Fan Motor Nameplate HP: 10 HP

Chilled Water Pump HP: 15 HP

Operation Schedule: 730 — 1630 M-F = 2346 HRS./YR.

Existing Time Clock Control: NO

Controls: ______

NOTES: ACTIVE YEAR ROUND

EMCS Function	KW	KWH	THERMS	MH
____ #1, Time Scheduled Operations	____	____	____	____
____ #2, Duty Cycling	____	____	____	____
____ #3, Demand Limiting Start/Stop	____	____	____	____
____ #12, Chilled Water Reset	____	____	____	____
____ #16, Start/Stop Optimization	____	____	____	____
____ #23, Maint. Run Time Reports	____	____	____	____
____ #24, Trouble Diagnosis	____	____	____	____
____ #26, Safety Alarms	____	____	____	____

(Savings columns: KW, KWH, THERMS, MH)

FIGURE 14 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-3, Single Zone Air Handler

Building System: 4

Supply CFM: 30000 Supply Fan HP: 30 Return Fan HP: 0

Economizer Status: COULD BE USED FOR ENTHALPY CONTROL

Min. O.A. CFM: 4500 Time Clock Control: NO

Occupancy Schedule: 730 – 1630 M-F = 2346 HRS./YR.

Critical Areas/Equipment: NONE

Controls: ______

NOTES: ______

EMCS Function	Savings KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___
___ #2, Duty Cycling	___	___	___	___
___ #3, Demand Limiting Start/Stop	___	___	___	___
___ #8, Enthalpy Economizer	___	___	___	___
___ #9, Space Night Setback	___	___	___	___
___ #16, Start/Stop Optimization	___	___	___	___
___ #23, Maint. Run Time Reports	___	___	___	___
___ #24, Trouble Diagnosis	___	___	___	___

FIGURE 15- SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-6, Multizone Air Handler

Building System: 5 Occupancy Schedule: 730-1630M-F

Number Zones: 3

Supply CFM: 18000 Supply Fan HP: 20 Return Fan HP: 0

Min. O.A. CFM: 1000 Time Clock Control: No

Cooling Coil Capacity: 540 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 370 MBH, Design Heating Coil LVG. Temp: 87

NOTES: ______

EMCS Function	Savings KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___
___ #2, Duty Cycling	___	___	___	___
___ #3, Demand Limiting Start/Stop	___	___	___	___
___ #8, Enthalpy Economizer	___	___	___	___
___ #9, Space Night Setback	___	___	___	___
___ #10, Hot/Cold Deck Reset	___	___	___	___
___ #16, Start/Stop Optimization	___	___	___	___
___ #23, Maint. Run Time Reports #24, Trouble Diagnosis	___	___	___	___

FIGURE 16- SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-6, Multizone Air Handler

Building System: 6 Occupancy Schedule: 24 HRS, 7 DAYS

Number Zones: 4

Supply CFM: 20000 Supply Fan HP: 30 Return Fan HP: 0

Min. O.A. CFM: 1200 Time Clock Control: No

Cooling Coil Capacity: 600 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 480 MBH, Design Heating Coil LVG. Temp: 90

NOTES: ____________________

EMCS Function	KW	KWH	THERMS	MH
____ #1, Time Scheduled Operation	____	____	____	____
____ #2, Duty Cycling	____	____	____	____
____ #3, Demand Limiting Start/Stop	____	____	____	____
____ #8, Enthalpy Economizer	____	____	____	____
____ #9, Space Night Setback	____	____	____	____
____ #10, Hot/Cold Deck Reset	____	____	____	____
____ #16, Start/Stop Optimization	____	____	____	____
____ #23, Maint. Run Time Reports #24, Trouble Diagnosis	____	____	____	____

(Savings columns: KW, KWH, THERMS, MH)

FIGURE 17- SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 400 System Schematic: S-14, Steam Boiler

Building System: 1

Fuel: #2 OIL

Peak Output Capacity: 3000 MBH Input at Peak Output: 4000 MBH

Operation Schedule: 730-1630 M-F

Controls: ____

NOTES: ____

EMCS Function	Savings KW	KWH	THERMS	MH
___ #23, Trouble Diagnosis	___	___	___	___
___ #26, Safety Alarm	___	___	___	___

FIGURE 18 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 400 System Schematic: S-13, Steam Unit Heater System

Building System: 2

Total Unit Heater Capacity: 2800 MBH

Occupancy Schedule: 730 - 1630 M-F

Occupied Hours of Operation: 2346 HRS/YR.

Occupied Temperature: 70 F Unoccupied Temperature 50 F

NOTES:

EMCS Function	Savings KW	KWH	THERMS	MH
____ #9, Space Night Setback				

FIGURE 19 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 500 System Schematic: S-7, Single Zone Split System

Building System: 1

Supply CFM: 15000 Supply Fan HP: 20 Return Fan HP: 0

Economizer Status : NOT EXISTING

Min. O.A. CFM: 1500 Time Clock Control: NO

Total Compressor HP: 40 Total Condenser Fan HP: 3

Occupancy Schedule: 730-1630 M-F = 2346 HRS./YR.

Critical Areas/Equipments: NONE

Controls: ____

NOTES: ____

EMCS Function	Savings KW	KWH	THERMS	MH
___ #1, Time Scheduled Operation	___	___	___	___
___ #2, Duty Cycling	___	___	___	___
___ #3, Demand Limiting Start/Stop	___	___	___	___
___ #8, Enthalpy Economizer	___	___	___	___
___ #9, Space Night Setback	___	___	___	___
___ #16, Start/Stop Optimization	___	___	___	___
___ #23, Maint. Run Time Reports	___	___	___	___
___ #24, Trouble Diagnosis	___	___	___	___

FIGURE 20 - SURVEY DATA FORMS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 500 System Schematic: S-1, Hot Water Boiler

Building System: 2

Operation Schedule: 24HRS., OCT.-APRIL Fuel: #2 OIL

Peak Output Capacity: 600 MBH Input at Peak Output: 850 MBH

H.W. Pump HP: 1 HP Annual Hours of Operation: 5040

Controls: ______

NOTES: ______

EMCS Function	KW	KWH	THERMS	MH
____ #14, O.A. Schedule Reset				
______				
______				
______				
____ #23, Maint. Run Time Reports				
____ #24, Trouble Diagnosis				
____ #26, Safety Alarms				

(Savings columns: KW, KWH, THERMS, MH)

FIGURE 21 - SURVEY DATA FORMS

3.6 ANALYSIS PRELIMINARIES

Analysis Preliminaries include preparatory activities necessary to perform the savings and cost analysis on each system/function considered for EMCS connection. These activities include gathering of unit cost estimating data to be used, determining and summarizing the procedure to be used in savings analysis of each system function, determinating current unit energy cost, preparing or adapting schematics for systems found during field investigation, etc.

Once the field investigation phase is completed, the EMCS designer should know exactly what energy consuming systems are present on the particular base. One of the next tasks to be undertaken is the preparation or adaptation of schematics of each type of system. Each system type schematic should represent the relative arrangement of the equipment which comprises the system and illustrate in some manner the interaction and control of each element of the system. The designer must then decide which EMCS functions may be applicable to each system type. Based on this decision, the sensors/ controllers required to perform each function must be shown on the schematic. The purpose of constructing the schematic in this manner is for use in evaluating the "field hardware duplicity" aspects of an EMCS. If for some reason the field devices are not shared by different functions, the schematics become trivial, since no "field hardware duplicity" would be present. Examples of schematics for various system types used in the Homestead AFB, Fairchild AFB, and Grand Forks AFB feasibility studies can be found in Section 2 of this report.

Once system type schematics have been constructed, cost data must be obtained for each EMCS device shown on each schematic. Basic cost estimating data are listed in Section 1.7, of this report. The cost figures shown must be escalated from the date they were obtained to the expected bid date for the project. Standard Air Force construction cost escalation techniques may be used for this task.

The basic utility cost information and rate schedules for the particular base must be obtained for use in energy savings calculations. The raw data should have been obtained as one of the list of requested items in the scope determination phase. Because utility prices and billing methods have been changing rapidly in recent years, the data obtained must be closely evaluated to determine the best prices for use in savings calculations. For instance, the electric utility serving a particular base may have recently changed its method of calculating demand charges. This could radically affect the electrical billings in the future and cannot be predicted from past bills. Once a good unit price for each type of savings is established for the present, these prices must be escalated to the date at which the EMCS will begin operation for payback calculations.

Before beginning calculation of savings resulting from EMCS control of each energy consuming system, the methods to be used for this calculation should be standardized and summarized. This is necessary for the consistent calculation of savings. Since the EMCS analysis is comparative in nature, the absolute accuracy of the savings calculations is not as important as a consistent method. Explanation of techniques used in savings calculations are included for each system type in Section 2 of this report. These are merely examples and many other techniques of greater or lesser accuracy may be used in the evaluation of potential savings. The choice of approach should be made by the EMCS design engineer. Most of the savings estimates may be made by simple manual calculations, however, some of the more critical functions require detailed building energy consumption simulations.

Detailed building energy consumption simulations require the use of computer programs for that purpose. There are many programs available for performing this type of simulation. Programs which have been used in the past include E-CUBE 75, AXCESS, and TRACE. Each of these programs can be used to adequately simulate such EMCS functions as night shutdown or setback. They are all limited however in their ability to adequately simulate EMCS optimization functions such as optimized start time, duty cycling with space temperature drift, hot/cold deck reset, etc. This limitation has been unavoidable since all

available programs were at more or less the same level of both load calculation and system simulation capabilities. Part of this problem will be solved shortly as a new generation of building analysis programs becomes available. These programs include APEC ESP-I, BLAST, E-CUBE 3, and CAL-ERDA. Each of these programs has limitations and differences in some areas, but they will generally enable more accurate evaluation of EMCS savings. Because these programs were not available at the time of this study, all examples and feasibility studies were performed using the E-CUBE 75 program.

3.6.1 SUMMARY OF STEPS:

1. Prepare/Adapt system type schematics to match actual systems found in field investigation phase.

2. Obtain unit EMCS device costs. Escalate according to applicable Air Force criteria.

3. Analyze utility cost date and rate structures to determine reasonable unit prices for energy savings. Escalate according to applicable Air Force criteria.

4. Determine and summarize savings calculations techniques to be used for the Base in question.

5. Determine functions and buildings for which computer building energy analysis must be performed.

6. Execute computer energy analysis programs and summarize results for use in savings calculations.

3.6.2 EXAMPLE

Utility cost data for John Doe AFB is contained on Figure 22. Savings calculation equations are summarized on Figure 23 thru 29. Computer building energy analysis summaries are included on Figure 30.

ENERGY COST ANALYSIS

ELECTRICAL:

The following data have been taken from Florida Power and Light Company Rate Schedule ML (LARGE U.S. Military Service) and the base electrical records:

DEMAND COST: \$1.75/KW/month

DEMAND INTERVAL = 30 minutes

RATCHET ADJUSTMENT = None, demand on a monthly basis

COMSUMPTION COST: \$.023/KWH (average cost, not including demand charges, taken from bill for 14 February 1977 to 16 March 1977).

ESCALATED RATES:

DEMAND: \$1.75 X 1.16 X 1.16 = \$2.355/KW/month

COMSUMPTION: \$0.023 X 1.16 X 1.16 = \$0.031/KWH

NOTE: An examination of electrical billings for several months indicates a large quantity of electricity being consumed by base housing. According to the recaps received, housing accounts for approximately 50% of the base electrical costs.

FUEL OIL:

The following data have been taken from base fuel records:

FUEL OIL COST: \$0.4269/gal (for #2 oil, delivered in March, 1977).

ESCALATED RATE: \$0.4269 x 1.16 X 1.16 = \$0.5744/gal

\$0.5744/gal/139 MBTU/gal = \$0.0041 3/MBTU

FIGURE 22 - UTILITY COST DATA

SYSTEM/FUNCTION SUMMARY

Hot Water Boiler — Schematic #S-1

Function #	Type	Savings
14	THERMS	H x .01 x I x 1/100 = H x I x .0001
23	MH	2
24	MH	2
26	MH	2

DX Unit, Air Cooled — Schematic #S-2

Function #	Type	Savings
1	KWH	0
2	KWH	0
3	KW	$(HP_1 + HP_2) \times .8 \times .746 \times .25 \times M = (HP_1 \times HP_2) \times M \times .149$
16	KWH	0
23	MH	2
24	MH	2
26	MH	2

FIGURE 23 - SAVINGS CALCULATION EQUATIONS

Single Zone Air Handler | Schematic #S-3

Function #	Type	Savings	
		NO TIME CLOCK	WITH TIME CLOCK
1	KWH	FAN: HP x .8 x .746 x (8760-H) x E = .5968 x HP x (8760-H)	x .3
	KWH	E^3 (COOLING)	x .3
	THERMS	E^3 (HEATING)	x .3
2	KWH	HP x .8 x 10/60 x H x .746 = HP x H x .0995	
3	KW	HP x .8 x .746 x .25 x M = HP x M x .1492	
8	KWH	E^3 (COOLING)	
9	KWH	FAN: HP x .746 x .8 x (8760-H) /2 = HP x (8760-H) x .2984	
	KWH	E^3 (COOLING)	
	THERMS	E^3 (HEATING)	
16	KWH	HP x .8 x .746 x .5 x OD = HP x OD x .2984	
23	MH	2	
24	MH	2	

FIGURE 24 - SAVINGS CALCULATION EQUATIONS

Terminal Reheat Air Handler

Schematic #S-4

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH	FAN: HP x .8 x .746 x (8760-H) x E = HP x (8760-H) x .5968	x .3
	KWH	E^3 (COOLING)	x .3
	THERMS	E^3 (HEATING)	x .3
2	KWH	HP x .8 x .746 x 10/60 x H = HP x H x .0995	
3	KW	HP x .8 x .746 x .25 x M = HP x M x .1492	
8	KWH	E^3 (COOLING)	
9	KWH	FAN: HP x .746 x .8 x (8760-H)/2) = HP x (8760-H) x .2984	
	KWH	E^3 (COOLING)	
	THERMS	E^3 (HEATING)	
11	KWH	E^3 (COOLING)	
16	KWH	HP x .8 x .746 x .5 x OD = HP x OD x .2984	
23	MH	2	
24	MH	2	

Chiller, Air Cooled

Schematic #S-5

Function #	Type	Savings
1	KWH	HP x .8 x .746 x (8760-H) = HP x (8760-H) x .5968
2	KWH	HP x H x .0995
3	KW	$(HP_1 + HP_2 + HP_3)$ x M x .1492
12	KWH	T x 1000 x 1 x .03 = T x 30
16	KWH	HP x OD x .2984
23	MH	2
24	MH	2
26	MH	2

FIGURE 25 - SAVINGS CALCULATION EQUATIONS

Multizone Air Handler

Schematic #S-6

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH	FAN: HP x (8760-H) x .5968	x .3
	KWH	E^3 (COOLING)	x .3
	THERMS	E^3 (HEATING)	x .3
2	KWH	HP x H x .0995	
3	KW	HP x M x .1492	
9	KWH	FAN: HP x (8760-H) x .2984	
	KWH	E^3 (COOLING)	
	THERMS	E^3 (HEATING)	
10	KWH	E^3	
	THERMS	E^3	
16	KWH	HP x OD x .2984	
23	MH	2	
24	MH	2	

Single Zone Split System

Schematic #S-7

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH	FAN: HP (8760-H) x .5968	x .3
	KWH	E^3 (COOLING)	x .3
	THERMS	E^3 (HEATING)	x .3
2	KWH	HP x H x .0995	
3	KW	$(HP_1 + HP_2 + HP_3)$ x M x .1492	
8	KWH	E^3 (COOLING)	
9	KWH	FAN: HP x (8760-H) x .2984	
	KWH	E^3 (COOLING)	
	THERMS	E^3 (HEATING)	
16	KWH	HP x OD x .2984	
23	MH	2	
24	MH	2	

FIGURE 26 - SAVINGS CALCULATION EQUATIONS

Chiller, Water Cooled

Schematic #S-8

Function #	Type	Savings NO TIME CLOCK	WITH TIME CLOCK
1	KWH	$(HP_1 + HP_2) \times (8760-H) \times .5968$	x .3
2	KWH	$(HP_1 + HP_2) \times H \times .0995$	
3	KWH	$(HP_1 + HP_2 + HP_3 + HP_4) \times M \times .1492$	
12	KW	T x 30	
13	KW	T x 45	
16	KW	$(HP_1 + HP_2) \times OD \times ,2984$	
23	MH	2	
24	MH	2	
26	MH	2	

Heating and Ventilating Unit

Schematic #S-9

Function #	Type	Savings NO TIME CLOCK	WITH TIME CLOCK
1	KWH THERMS	HP x (8760-H) x .5968 E^3 (HEATING - ONLY)	x .3 x .3
2	KWH	HP x H x .0995	
3	KW	HP x M x .1492	
9	KWH THERMS	FANS: HP (8760-H) x .2984 E^3 (HEATING)	
16	KWH	HP x OD x .2984	
23	MH	2	
24	MH	2	

FIGURE 27 - SAVINGS CALCULATION EQUATIONS

Convector Heating System

Schematic #S-10

Function #	Type	Savings
9	KWH THERMS	FAN: HP (8760-H) x .2984 E^3 (HEATING)
23	MH	2
24	MH	2

Hot Water Convertor

Schematic #S-11

Function #	Type	Savings
14	THERMS	H x I x .01 x 1/100 = H x I x .0001
24	MH	2

Two Pipe Fan Coil System

Schematic #S-12

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH	DUAL TEMP PUMP: .5968 x HP x (8760-H)	x .3
	KWH	E^3 (COOLING)	x .3
	THERMS	E^3 (HEATING)	x .3
2	KWH	HP x H x .0995	
3	KW	HP x M x .1492	
9	KWH KWH THERMS	FAN: HP x (8760-H) x .2984 E^3 (COOLING) E^3 (HEATING)	
16	KWH	HP x OD x .2984	
23	MH	2	
24	MH	2	

FIGURE 28 - SAVINGS CALCULATION EQUATIONS

Steam Unit Heater System

Schematic #S-13

Function #	Type	Savings
9	THERMS	E^3 (HEATING)

Steam Boiler

Schematic #S-14

Function #	Type	Savings
24	MH	2
26	MH	2

Direct Fired Furnace

Schematic #S-15

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH THERMS	FAN: HP x (8760-H) x .5968 E^3 (HEATING)	x .3 x .3
9	KWH THERMS	FAN: HP x (8760-H) x .2984 E^3 (HEATING)	
23	MH	2	
24	MH	2	

DX Unit, Water Cooled

Schematic #S-16

Function #	Type	Savings: NO TIME CLOCK	WITH TIME CLOCK
1	KWH	COND. PUMP: HP x (8760-H) x .5968	x .3
2	KWH	COND. PUMP: HP x H x .0995	
3	KW	$(HP_1 + HP_2 + HP_3)$ x M x .149	
13	KWH	T x 45	
16	KWH	COND. PUMP: HP x OD x .2984	
23	MH	2	
24	MH	2	
[illegible]	MH	2	

FIGURE 29 - SAVINGS CALCULATION EQUATIONS

		BASE COMPUTER RUN		REVISED COMPUTER RUN		ANNUAL SAVINGS			
SYSTEM TYPE	BUILDING OCCUPANCY	RUN #	SYSTEM OPERATION	RUN #	SYSTEM OPERATION	FUEL, THERMS	ELEC, KWH	THERMS	KWH
Single Zone Air Handler	Office 7am-4pm M-F	H1	24 hours	H2	Night Shutdown	530	34267	0.0488/cfm	3.158/cfm
Single Zone Air Handler	Office 7am-4pm	H2	Night Shutdown	H3	Add enthalpy economizer	0	4251	0.	0.392/cfm
Multizone Air Handler	7am-4pm M-F	H15	24 hours	H16	Night Shutdown	12870	156460	0.666/cfm	8.094/cfm
Multizone Air Handler	7am-4pm M-F	H15	24 hours	H17	Hot/Cold Deck Temperature Reset	3780	28130	0.196/cfm	1.455/cfm
Unit Heater System	Office 7am-4pm	H1	24 hours	H2	Night Shutdown	530	0	1.104/mbh	0.

FIGURE 30 - COMPUTER BUILDING ENERGY ANALYSIS SUMMARIES

3.7 SAVINGS ESTIMATION

The Savings Estimation effort is the system by system selection of applicable EMCS functions and the estimation of savings which would result from the application of each of those functions.

Once the data gathered during field investigation are recorded on survey sheets, the EMCS functions applicable to each system must be selected. The survey data sheets used in this study include a listing of the functions which may be applied to each type of system. The design engineer then selects those functions on the survey sheet which he feels can be applied to a particular system. This selection is based on the field investigation data. For example, the EMCS functions which would be applied to an air handling unit serving an administrative area would not be the same as those for an air handling unit serving a hospital operating room. The EMCS design engineer must use his experience in selecting the applicable EMCS functions for each system.

Once the EMCS functions for each system have been selected, the savings which will result from each system/function must be estimated. The equations used to calculate these savings are derived during the analysis preliminaries step. Variables in these equations are filled with the data obtained during the field investigation. In general, the savings calculated are of four types. These are 1) electrical peak demand reduction (KW), 2) electrical consumption reduction (KWH), 3) heating energy consumption reduction (THERMS), and 4) manpower savings (MANHOURS). Savings should be calculated in these units and then converted to dollars for summation. This approach will assure that totals for each type of savings may be obtained at the end of the design analysis. If the savings equations and calculations produce results directly in dollars, it would not be possible to determine the major source of savings, whether it be KW demand, heating savings, etc.

3.7.1 SUMMARY OF STEPS:

1. Select appropriate functions for each system based on data from the field investigation.

2. Calculate estimated savings from each selected function applied to each system.

3.7.2 EXAMPLE:

Savings calculations are shown on Figure 31 thru 45.

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-1, Hot Water Boiler

Building System: 1

Operation Schedule: 730-1630 M-F Fuel: #2 OIL

Peak Output Capacity: 750 MBH Input at Peak Output: 1000 MBH

H.W. Pump HP: 3/4 HP Annual Hours of Operation: 24HRS. OCT.-April = 5040

Controls:

NOTES: 5040 Hrs./Yr.

EMCS Function	Tot. $	KW	KWH	THERMS	MH
X #14, O.A.Schedule Reset	208			504	
5040 X 1000 X 0.0001					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2
X #26, Safety Alarms	20				2

FIGURE 31 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-5, Chiller - Air Cooled

Building System: 2

Total System Capacity: 40 Tons

Total Compressor Motor Nameplate HP: 40 HP

Total Condenser Fan Motor Nameplate HP: 5 HP

Chilled Water Pump HP: 3 HP

Operation Schedule: 730-1630 M-F 2346 Hrs./Yr.

Existing Time Clock Control: No

Controls:

NOTES: DISCONNECTED FROM OCT. 30.-APRIL 1: 8760X6/12 = 4380 Hrs/YR. 2346X6/12 = 1173 Hrs./YR.

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operations	178		5742		
3X(4380-1173) X 0.5968					
X #2, Duty Cycling	22		700		
3X2346 X 0.0995					
X #3, Demand Limiting Start/Stop	101	43			
48X6 X 0.1492					
#12, Chilled Water Reset	—				
X #16, Start/Stop Optimization	4		116		
3X130 X 0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2
X #26, Safety Alarms	20				2

FIGURE 32 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 100 System Schematic: S-6, Multizone Air Handler

Building System: 3 Occupancy Schedule: 730-1630M-F

Number Zones: 5

Supply CFM: 16000 Supply Fan HP: 15 Return Fan HP: 0

Min. O.A. CFM: 1600 Time Clock Control: NO

Cooling Coil Capacity: 480 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 300 MBH, Design Heating Coil LVG. Temp: 85

NOTES: BOILER OR CHILLER SHUT OFF WHEN OTHER ON, AIR UNIT OPERATES - LIKE SINGLE ZONE UNIT.

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operation	3669		107,946	781	
15X(8760-2346)X0.5968 = 57418 KWH					
Clg.: 16000X3.158 = 50528 KWH					
Htg.: 16000X0.0488 = 781 THERMS					
X #2, Duty Cycling	109		3501		
15X2346X0.0995					
X #3, Demand Limiting Start/Stop	63	26.9			
15X12X0.1492					
#8, Enthalpy Economizer	—				
#9, Space Night Setback	—				
#10, Hot/Cold Deck Reset	—				
X #16, Start/Stop Optimization	36		1164		
15X260X0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2

FIGURE 33 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 200 System Schematic: S-14, Steam Boiler

Building System: 1

Fuel: #2 OIL

Peak Output Capacity: 500 MBH Input at Peak Output: 650 MBH

Operation Schedule: OCT. — MAY

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #23, Trouble Diagnosis	20				2
X #26, Safety Alarm	20				2

FIGURE 34 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 200 System Schematic: S-7, Single Zone Split System

Building System: 2

Supply CFM: 8000 Supply Fan HP: 5 Return Fan HP: 0

Economizer Status : COULD BE USED FOR ENTHALPY CONTROL

Min. O.A. CFM: 1200 Time Clock Control: YES

Total Compressor HP: 20 Total Condenser Fan HP: 2

Occupancy Schedule: 730—1630 M-F = 2346 HRS./YR.

Critical Areas/Equipments: NONE

Controls:

NOTES:

	EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X	#1, Time Scheduled Operation	506		14756	117	
	5X(8760-2346)X0.746X0.3=7177KWH					
	Clg.: 8000X3.158=25264KWH X 0.3=7579					
	Htg.: 8000X0.0488=390THERMS X0.3=117					
X	#2, Duty Cycling	36		1167		
	5X2346X0.0995					
X	#3, Demand Limiting Start/Stop	57	24			
	27X6X0.1492					
X	#8, Enthalpy Economizer	97		3136		
	8000X0.392					
	#9, Space Night Setback	—				
X	#16, Start/Stop Optimization	12		388		
	5X260X0.2984					
X	#23, Maint. Run Time Reports	20				2
X	#24, Trouble Diagnosis	20				2

FIGURE 35 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-1, Hot Water Boiler

Building System: 1

Operation Schedule: 730—1630 M-F Fuel: #2 OIL

Peak Output Capacity: 1500 MBH Input at Peak Output: 2000 MBH

H.W. Pump HP: 5 HP Annual Hours of Operation: 5040

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #14, O.A.Schedule Reset	416			1008	
5040 X 2000 X 0.0001					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2
X #26, Safety Alarms	20				2

FIGURE 36 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-1, Hot Water Boiler

Building System: 2

Operation Schedule: 730-1630 M-F Fuel: #2 OIL

Peak Output Capacity: 1500 MBH Input at Peak Output: 2000 MBH

H.W. Pump HP: 5 HP Annual Hours of Operation: 8760

Controls:

NOTES:

EMCS Function	Tot. $	KW	KWH	THERMS	MH
X #14, O.A. Schedule Reset	416			1008	
5040X2000X0.0001					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2
X #26, Safety Alarms	20				2

FIGURE 37 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-5, Chiller - Air Cooled

Building System: 3

Total System Capacity: 160 Tons

Total Compressor Motor Nameplate HP: 200 HP

Total Condenser Fan Motor Nameplate HP: 10 HP

Chilled Water Pump HP: 15 HP

Operation Schedule: 730 – 1630 M-F, 2346 HRS./YR.

Existing Time Clock Control: No

Controls:

NOTES: ACTIVE YEAR ROUND

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operations	1780		57418		
15X(8760-2346)X0.5968					
#2, Duty Cycling	—				
X #3, Demand Limiting Start/Stop	949	403			
225X12X0.1492					
X #12, Chilled Water Reset	149		4800		
160X30					
X #16, Start/Stop Optimization	35		1119		
15X250X0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2
X #26, Safety Alarms	20				2

FIGURE 38 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-3, Single Zone Air Handler

Building System: 4

Supply CFM: 30000 Supply Fan HP: 30 Return Fan HP: 0

Economizer Status: COULD BE USED FOR ENTHALPY CONTROL

Min. O.A. CFM: 4500 Time Clock Control: NO

Occupancy Schedule: 730 — 1630 M-F, 2346 HRS./YR.

Critical Areas/Equipment: NONE

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operation	7101		209576	1464	
30X(8760-2346)X0.5968= 114,836 KWH					
Clg.: 30000X3.158 = 94740 KWH					
Htg.: 30000X0.0488 = 1464 THERMS					
X #2, Duty Cycling	217		7003		
30X2346X0.0995					
X #3, Demand Limiting Start/Stop	127	53.7			
30X12X0.1492					
X #8, Enthalpy Economizer	365		11760		
30000 X 0.392					
#9, Space Night Setback	—				
X #16, Start/Stop Optimization	72		2328		
30X260X0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2

FIGURE 39 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-6, Multizone Air Handler

Building System: 5 Occupancy Schedule: 730-1630 M-F

Number Zones: 3

Supply CFM: 18000 Supply Fan HP: 20 Return Fan HP: 0

Min. O.A. CFM: 1000 Time Clock Control: No

Cooling Coil Capacity: 540 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 370 MBH, Design Heating Coil LVG. Temp: 87

NOTES:

EMCS Function	Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operation	11841		222250	11988	
FAN 20X(8760-2346)X0.5968=76558 KWH					
Clg.: 18000X8.094=145,692					
Htg.: 18000X0.666=11988					
X #2, Duty Cycling	145		4669		
20X2346X0.0995					
X #3, Demand Limiting Start/Stop	84	35.8			
20X12X0.1492					
#8, Enthalpy Economizer					
#9, Space Night Setback					
#10, Hot/Cold Deck Reset					
X #16, Start/Stop Optimization	48		1552		
20X260X0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2

FIGURE 40 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 300 System Schematic: S-6, Multizone Air Handler

Building System: 6 Occupancy Schedule: 24HRS, 7DAYS

Number Zones: 4

Supply CFM: 20000 Supply Fan HP: 30 Return Fan HP: 0

Min. O.A. CFM: 1200 Time Clock Control: NO

Cooling Coil Capacity: 600 MBH, Design Cooling Coil LVG. Temp: 55

Heating Coil Capacity: 480 MBH, Design Heating Coil LVG. Temp: 90

NOTES:

	EMCS Function	Savings				
		Tot. $	KW	KWH	THERMS	MH
	#1, Time Scheduled Operation	—				
X	#2, Duty Cycling	810		26149		
	30X8760X0.0995					
X	#3, Demand Limiting Start/Stop	127	53.7			
	30X12X0.1492					
	#8, Enthalpy Economizer	—				
	#9, Space Night Setback	—				
X	#10, Hot/Cold Deck Reset	2521		29100	3920	
	20000X1.455					
	20000X0.196					
X	#16, Start/Stop Optimization	72		2328		
	30X260X0.2984					
X	#23, Maint. Run Time Reports	20				2
X	#24, Trouble Diagnosis	20				2

FIGURE 41 - SAVINGS CALCULATIONS

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ENERGY MONITORING AND CONTROL SYSTEM (EMCS) APPLICATION STUDY, --ETC(U)
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UNCLASSIFIED AFCEC-TR-78-7-VOL-1 NL

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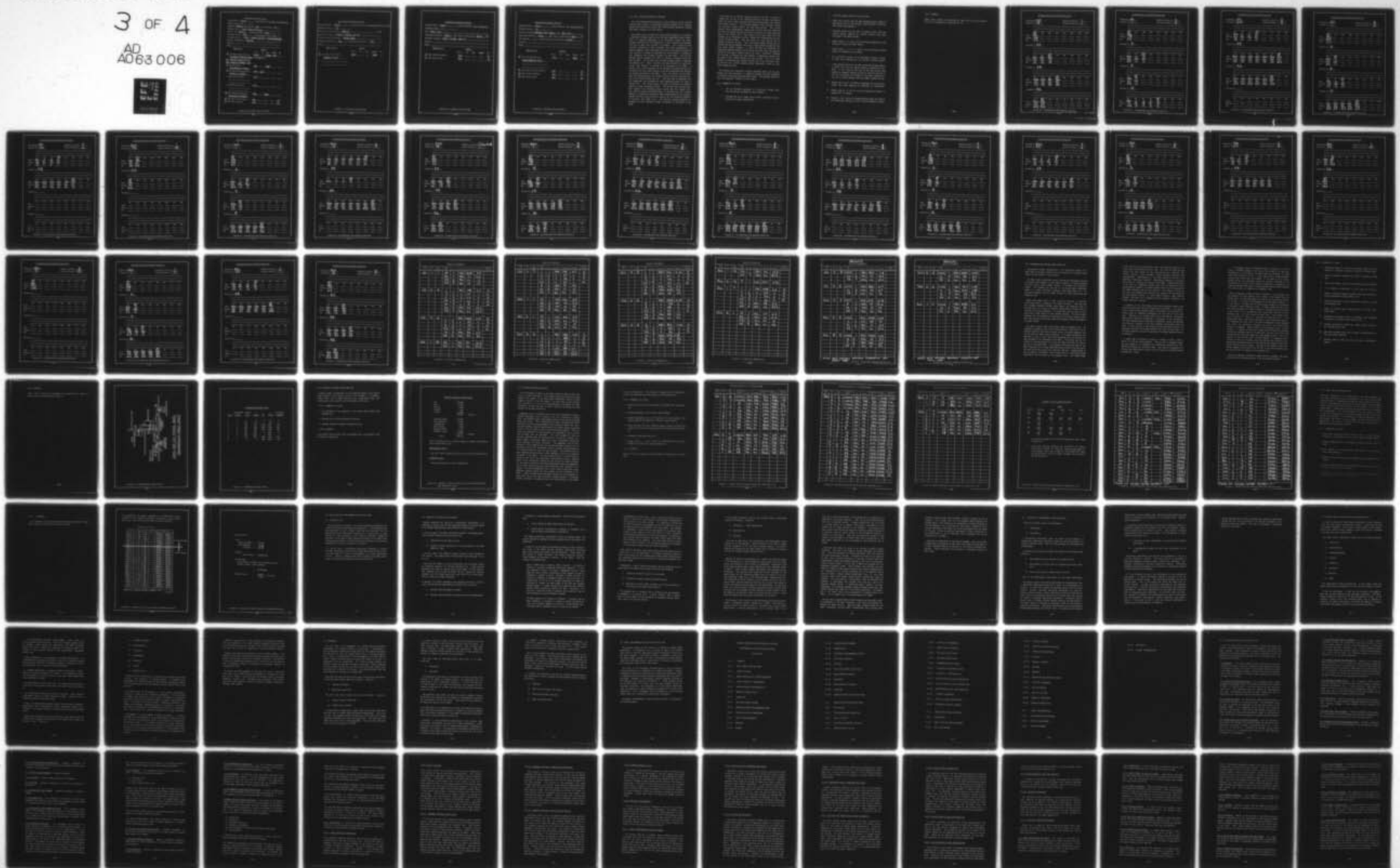

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 500 System Schematic: S-7, Single Zone Split System

Building System: 1

Supply CFM: 15000 Supply Fan HP: 20 Return Fan HP: 0

Economizer Status : NOT EXISTING

Min. O.A. CFM: 1500 Time Clock Control: NO

Total Compressor HP: 40 Total Condenser Fan HP: 3

Occupancy Schedule: 730 - 1630 M-F = 2346 HRS/YR.

Critical Areas/Equipments: NONE

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #1, Time Scheduled Operation	4142		123,928	732	
20X(8760-2346)X0.5968 = 76,558 KWH					
Clg.: 15000X3.158 = 47370					
Htg.: 15000X0.0488 = 732					
X #2, Duty Cycling	145		4669		
20X2346X0.0995					
X #3, Demand Limiting Start/Stop	133	56.4			
63X6X0.1492					
___ #8, Enthalpy Economizer	—				
___ #9, Space Night Setback	—				
X #16, Start/Stop Optimization	48		1552		
20X260X0.2984					
X #23, Maint. Run Time Reports	20				2
X #24, Trouble Diagnosis	20				2

FIGURE 42- SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 400 System Schematic: S-13, Steam Unit Heater System

Building System: 2

Total Unit Heater Capacity: 2800 MBH

Occupancy Schedule: 730 — 1630 M-F

Occupied Hours of Operation: 2346 HRS.

Occupied Temperature: 70 F Unoccupied Temperature 50 F

NOTES:

EMCS Function	Tot. $	KW	KWH	THERMS	MH
X #9, Space Night Setback	1277			3091	

2800 X 1.104

FIGURE 43 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 400 System Schematic: S-14, Steam Boiler

Building System: 1

Fuel: #2 OIL

Peak Output Capacity: 3000 MBH Input at Peak Output: 4000 MBH

Operation Schedule: 730 — 1630 M-F

Controls:

NOTES:

EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X #23, Trouble Diagnosis	20				2
X #26, Safety Alarm	20				2

FIGURE 44 - SAVINGS CALCULATIONS

SYSTEM/FUNCTION/SAVINGS ANALYSIS

Building Number: 500 System Schematic: S-1, Hot Water Boiler

Building System: 2

Operation Schedule: 24 HRS.-OCT.-APRIL Fuel: #2 OIL

Peak Output Capacity: 600 MBH Input at Peak Output: 850 MBH

H.W. Pump HP: 1 HP Annual Hours of Operation: 5040

Controls:

NOTES:

	EMCS Function	Savings Tot. $	KW	KWH	THERMS	MH
X	#14, O.A. Schedule Reset	177			428	
	5040 X 850 X 0.0001					
X	#23, Maint. Run Time Reports	20				2
X	#24, Trouble Diagnosis	20				2
X	#26, Safety Alarms	20				2

FIGURE 45 - SAVINGS CALCULATIONS

3.8 COST ESTIMATE/RANKING PROCESS

The Cost Estimate/Ranking Process is the system by system analysis whereby each function is economically ranked according to its payback period while taking into account the "field hardware duplicity" concept described in Section 1.5 of this report.

The method used to account for field hardware duplicity is to perform a repetitive ranking process on the functions applicable to each system. First, all functions applicable to the particular system are listed. Savings resulting from the application of each function are estimated. The cost to apply each function is estimated. This is done for each function, assuming no other functions are under consideration. A system schematic which illustrates what sensors are required to perform each function is needed to accomplish this cost estimate. Examples of such schematics are included in Section 2 of this report. The cost and savings figures obtained are used to calculate a payback period for each function. The function with the best payback period is assigned the highest rank. When a function has been ranked for a particular system, that function is assumed to be connected to the EMCS. A revised cost is then calculated for the remaining unranked functions on the basis that the ranked functions (and their associated field devices) are already connected to the EMCS. Thus, any sensors or controllers that are common between the ranked function and the remaining functions have already been paid for. Their cost may be deducted from the independent cost estimates for each remaining function to obtain a revised cost. The revised costs are used to calculate new payback periods for each remaining function. The function with the best payback period of the remaining group is given the next highest rank. The iterative process described above is continued until all functions applied to a particular system have been ranked based on their payback periods and their costs revised to account for the previous connection of functions with higher rank. The function ranking procedure is repeated for each individual system considered for connection to the EMCS.

One result of the function ranking process is that after a function is ranked and the cost of the remaining functions revised, the payback period for one or more unranked functions could be better than some of the ranked functions. The extreme example of this situation is when two functions require exactly the same field devices. The ranking process would independently analyze each function and then select the one with the highest savings (since each would have the same calculated cost) to be ranked first. The process would then revise the cost estimate of the remaining function, taking into consideration the previously ranked function. This will result in a zero cost for the remaining unranked function. Thus, the ranking would actually show a function having the highest rank with a lower payback period than the next lower ranked function. If these functions are combined, the resulting combined payback period would be better than the payback period of the higher ranked function by itself. Therefore, following the ranking of functions for each system, a combination process must be done on the ranked functions for each system. This is a simple process of examining each ranked function and, if the next lower ranked function has a better payback period, combining it with the next lower ranked function.

The ranking and combination process described above can be quite tedious and time consuming. A computer program has been developed to perform the ranking and combination tasks. This program and/or its use is documented in Volume II of this report.

3.8.1 SUMMARY OF STEPS:

1. List all functions applicable for a particular system along with the savings calculated for each function.

2. Calculate the cost to apply each function, assuming no other functions are under consideration.

3. Calculate payback period for each function.

4. Select the function with the best payback period, assign an appropriate rank to that function, and eliminate it from further ranking consideration.

5. Calculate revised cost for each unranked function while assuming devices required for ranked functions have been connected to the EMCS already.

6. Repeat steps 3, 4, and 5 until all functions applicable to the particular system have been ranked.

7. Repeat steps 1, 2, 3, 4, 5, and 6 until the function ranking analysis is complete for all systems.

8. For a particular system, list all applicable functions in order of their rank established by the function ranking analysis.

9. If the payback period of the next to the top ranked function is better than the top ranked function, combine the functions. If not, move to the next to the top function and compare its payback period with that of the next function on the list and combine the functions if the lower ranked function has a better payback than the higher ranked function.

10. Repeat step 9 until all functions applicable to the particular system have been examined as candidates for combination.

11. Repeat steps 8, 9, and 10 until the combination process is complete for all systems.

12. Prepare a final listing of system/functions after the ranking and combination process for use in the prioritization analysis.

3.8.2 EXAMPLE:

Steps 1 thru 7 above are illustrated on Figure 46 thru 67 and Steps 8 thru 12 are illustrated on Figures 68 thru 73.

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 100 Building System # 1

Function # 14 System Schematic 1

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1150							
Saving	208							
PB	5.5							

Function # 23

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	300	300					
Saving	20	20	20					
PB	15	15	15					

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1550	1050	800	500				
Saving	20	20	20	20				
PB	77	52	40	25				

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250	250						
Saving	20	20						
PB	12.5	12.5						

FIGURE 46 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 100 | Building System # 2
Function # 1 | System Schematic 5

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	178							
PB	2.5							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	22	22	22					
PB	20	0	0					

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	101	101						
PB	4.5	0						

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0	0	0			
Saving	4	4	4	4	4			
PB	113	0	0	0	0			

FIGURE 47 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 100 Building System # 2

Function # 23 System Schematic 5

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1800	1500	1500	1500	1500	1500	1250	
Saving	20	20	20	20	20	20	20	
PB	90	75	75	75	75	75	62.5	

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250	250	250	250	250	250		
Saving	20	20	20	20	20	20		
PB	12.5	12.5	12.5	12.5	12.5	12.5		

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 48 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 100 Building System # 3

Function # 1 System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	3669							
PB	0.12							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	109	109						
PB	4.2	0						

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	63	63	63					
PB	7.1	0	0					

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250			
Saving	36	36	36	36	36			
PB	19.4	6.9	6.9	6.9	6.9			

FIGURE 49 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 100 — Building System # 3

Function # 23 — System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	1000	1000		
Saving	20	20	20	20	20	20		
PB	65	50	50	50	50	50		

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 50 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 200 Building System # 1

Function # 24 System Schematic 14

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1000	750						
Saving	20	20						
PB	50	37.5						

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250							
Saving	20							
PB	12.5							

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 51 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 200 Building System # 2

Function # 1 System Schematic 7

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	506							
PB	0.9							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	36	36	36					
PB	12.5	0	0					

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	57	57						
PB	7.9	0						

Function # 8

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1320	1320	1320	1320	1320			
Saving	97	97	97	97	97			
PB	13.6	13.6	13.6	13.6	13.6			

FIGURE 52 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 200 Building System # 2

Function # 16 System Schematic 7

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250	250		
Saving	12	12	12	12	12	12		
PB	58	21	21	21	21	21		

Function # 23

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving								
PB								

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	1000	750	500	
Saving	20	20	20	20	20	20	20	
PB	65	50	50	50	50	37.5	25	

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 53 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 | Building System # 1 (same for #2)

Function # 14 | System Schematic 1

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1150							
Saving	416							
PB	2.8							

Function # 23

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	300	300					
Saving	20	20	20					
PB	15	15	15					

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1550	1050	800	500				
Saving	20	20	20	20				
PB	77	52	40	25				

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250	250						
Saving	20	20						
PB	12.5	12.5						

FIGURE 54 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 3

Function # 1 System Schematic 5

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	1780							
PB	0.25							

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	949	949						
PB	.48	0						

Function # 12

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1450	1150	1150	1150	1150			
Saving	149	149	149	149	149			
PB	9.7	7.7	7.7	7.7	7.7			

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	35	35	35					
PB	12.8	0	0					

FIGURE 55 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 3

Function # 23 System Schematic 5

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1800	1500	1500	1500	1500	1010	750	
Saving	20	20	20	20	20	20	20	
PB	90	75	75	75	75	50	37.5	

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250	250	250	250	250	250		
Saving	20	20	20	20	20	20		
PB	12.5	12.5	12.5	12.5	12.5	12.5		

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 56 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 4

Function # 1 System Schematic 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	7101							
PB	0.06							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	217	217						
PB	2.1							

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	126	126	126					
PB	3.6	0	0					

Function # 8

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1320	1320	1320	1320	1320	1320		
Saving	365	365	365	365	365	365		
PB	3.6	3.6	3.6	3.6	3.6	3.6		

FIGURE 57 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 | Building System # 4
Function # 16 | System Schematic 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250			
Saving	72	72	72	72	72			
PB	9.7	3.5	3.5	3.5	3.5			

Function # 23

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	1000	750	500	
Saving	20	20	20	20	20	20	20	
PB	65	50	50	50	50	37.5	25	

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 58 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 5

Function # 1 System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	11841							
PB	0.04							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	145	145						
PB	0.3	0						

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	84	84	84					
PB	5.4	0	0					

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250			
Saving	48	48	48	48	48			
PB	14.6	5.2	5.2	5.2	5.2			

FIGURE 59 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 5

Function # 23 System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	1000	1000		
Saving	20	20	20	20	20	20		
PB	65	50	50	50	50	50		

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 60 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 Building System # 6

Function # 2 System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	810							
PB	0.56							

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	127	127						
PB	3.5	0						

Function # 10

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	3200	3200	3200	3200				
Saving	2521	2521	2521	2521				
PB	1.28	1.28	1.28	1.28				

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250			
Saving	72	72	72	72	72			
PB	9.7	3.5	3.5	3.5	3.5			

FIGURE 61 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 300 | Building System # 6

Function # 23 | System Schematic 6

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0					
Saving	20	20	20					
PB	15	0	0					

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	500	500		
Saving	20	20	20	20	20	20		
PB	65	50	50	50	25	25		

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 62 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 400 Building System # 1

Function # 24 System Schematic 14

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1000	750						
Saving	20	20						
PB	50	37.5						

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250							
Saving	20							
PB	12.5							

Function # ________

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function # ________

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 63 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 400 Building System # 2

Function # 9 System Schematic 13

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1200							
Saving	1277							
PB	0.95							

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function #

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 64 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 500　　　Building System # 1

Function # 1　　　System Schematic 7

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450							
Saving	4144							
PB	0.11							

Function # 2

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0						
Saving	145	145						
PB	3.1	0						

Function # 3

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	450	0	0					
Saving	133	133	133					
PB	3.4	0	0					

Function # 16

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	700	250	250	250	250			
Saving	48	48	48	48	48			
PB	15.6	5.2	5.2	5.2	5.2			

FIGURE 65 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 500 Building System # 1

Function # 23 System Schematic 7

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	0	0	0				
Saving	20	20	20	20				
PB	15	0	0	0				

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1300	1000	1000	1000	1000	750		
Saving	20	20	20	20	20	20		
PB	65	50	50	50	50	37.5		

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

Function # ______

	#1	#2	#3	#4	#5	#6	#7	#8
Cost								
Saving								
PB								

FIGURE 66 - SYSTEM/FUNCTION RANKING ANALYSIS

SYSTEM/FUNCTION RANKING ANALYSIS

Building # 500 Building System # 2

Function # 14 System Schematic 1

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1150							
Saving	177							
PB	6.5							

Function # 23

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	300	300	300					
Saving	20	20	20					
PB	15	15	15					

Function # 24

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	1550	1050	800	500				
Saving	20	20	20	20				
PB	77	52	40	25				

Function # 26

	#1	#2	#3	#4	#5	#6	#7	#8
Cost	250	250						
Saving	20	20						
PB	12.5	12.5						

FIGURE 67 - SYSTEM/FUNCTION RANKING ANALYSIS

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
100	1	1	14	1	1150	208	5.5	
			26	2	250	20	12.5	
			23	3	300	20	15	
			24	4	500	20	25	
100	2	5	1	1	450	178	2.5	X
			3	2	0	101	0	X
			2	3	0	22	0	X
			23	4	0	20	0	X
			16	5	0	4	0	X
			26	6	250	20	12.5	
			24	7	1250	20	62.5	
100	3	6	1	1	450	3669	0.12	X
			2	2	0	109	0	X
			3	3	0	63	0	X
			23	4	0	20	0	X
			16	5	250	36	6.9	
			24	6	1000	20	50	
200	1	14	26	1	250	20	12.5	
			24	2	750	20	37.5	

FIGURE 68 - FUNCTION COMBINATION

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
200	2	7	1	1	450	506	0.9	X
			3	2	0	57	0	X
			2	3	0	36	0	X
			23	4	0	20	0	X
			8	5	1320	97	13.6	
			16	6	250	12	21	
			24	7	500	20	25	
300	1	1	14	1	1150	416	2.8	
			26	2	250	20	12.5	
			23	3	300	20	15	
			24	4	500	20	25	
300	2	1	14	1	1150	416	2.8	
			26	2	250	20	12.5	
			23	3	300	20	15	
			24	4	500	20	25	
300	3	5	1	1	450	1780	0.25	X
			3	2	0	949	0	X
			16	3	0	35	0	X
			23	4	0	20	0	X
			12	5	1150	149	7.7	
			26	6	250	20	12.5	
			24	7	750	20	37.5	

FIGURE 69 - FUNCTION COMBINATION

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
300	4	3	1	1	450	7101	0.06	X
			2	2	0	217	0	X
			3	3	0	126	0	X
			23	4	0	20	0	X
			16	5	250	72	3.5	
			8	6	1320	365	3.6	
			24	7	500	20	25	
300	5	6	1	1	450	11841	0.04	X
			2	2	0	145	0	X
			3	3	0	84	0	X
			23	4	0	20	0	X
			16	5	250	48	5.2	
			24	6	1000	20	50	
300	6	6	2	1	450	810	0.56	X
			3	2	0	127	0	X
			23	3	0	20	0	X
			10	4	3200	2521	1.28	
			16	5	250	72	3.5	
			24	6	500	20	25	

FIGURE 70 - FUNCTION COMBINATION

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
400	1	14	26	1	250	20	12.5	
			24	2	750	20	37.5	
400	2	13	9	1	1200	1277	0.95	
500	1	7	1	1	450	4144	0.11	X
			2	2	0	145	0	X
			3	3	0	133	0	X
			23	4	0	20	0	X
			16	5	250	48	5.2	
			24	6	750	20	37.5	
500	2	1	14	1	1150	177	6.5	
			26	2	250	20	12.5	
			23	3	300	20	15	
			24	4	500	20	25	

FIGURE 71 - FUNCTION COMBINATION

RESULTS

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
100	2	5	1.03022316	1	450	325	2.5	
			26	6	250	20	12.5	
			24	7	1250	20	62.5	
100	3	6	1.020323	1	450	3861	0.117	
			16	5	250	36	6.9	
			24	6	1000	20	50	
200	2	7	1.030223	1	450	619	0.73	
			8	5	1320	97	13.6	
			16	6	250	12	21	
			24	7	500	20	25	
300	3	5	1.031623	1	450	2784	0.162	
			12	5	1150	149	7.7	
			26	6	250	20	12.5	
			24	7	750	20	37.5	
300	4	3	1.020323	1	450	7464	0.06	
			16	5	250	72	3.5	
			8	6	1320	365	3.6	
			24	7	500	20	25	

NOTE: ONLY SYSTEMS REQUIRING COMBINATION ARE SHOWN HERE

FIGURE 72 - FUNCTION COMBINATION RESULTS

RESULTS

FUNCTION COMBINATION

Bldg. #	Sys. #	Sys. Type	Func. Type	Rank	Cost	Savings	Payback	To Be Combined
300	5	6	1.020323	1	450	12090	0.037	
			16	5	250	48	5.2	
			24	6	1000	20	50	
300	6	6	2.0323	1	450	957	0.47	
			10	4	3200	2521	1.28	
			16	5	250	72	3.5	
			24	6	500	20	25	
500	1	7	1.020323	1	450	4442	0.10	
			16	5	250	48	5.2	
			24	6	750	20	37.5	

NOTE: ONLY SYSTEMS REQUIRING COMBINATION ARE SHOWN HERE

FIGURE 73 - FUNCTION COMBINATION RESULTS

3.9 TRANSMISSION SYSTEM CONFIGURATION

Transmission System Configuration is the conceptual design of the EMCS data transmission network and the estimation of the costs associated with each element of that network.

The EMCS data transmission network includes all equipment required to transfer data between a field interface device in a remote building and the central control center (usually in the Base Civil Engineer's Office). The network may use any of the common data transmission media, i.e., radio, microwave, telephone, high speed cable, etc. The two most commonly used for EMCS projects are high speed cable and telephone lines.

Where high speed cable is used a coaxial, twinaxial, or specially constructed cable is installed by the EMCS contractor. The cable may be installed alongside existing aerial power and telephone lines on existing poles, or it may be installed underground by direct burial or through an existing ductbank. A single cable may be used to carry data from a large number of field interface devices. The most common problems occur from lightning interference for the aerial installed cable, and from cutting of the buried cable while digging without knowledge of the cable location.

The other primary data transmission media are telephone lines. By installing a modem at each field interface device, along with a corresponding modem at the central control center, low grade telephone lines may be used for EMCS data transmission. The great advantage of this approach is that in most cases spare telephone lines are existing into each building to be connected to the EMCS. These lines may be furnished by the government for use by the EMCS contractor at little or no cost to the government. This approach eliminates the need for the EMCS contractor to run high speed cable with a branch into each building and thus offers great cost reduction potential. Disadvantages of using telephone transmission media include the low transmission speed required by the low quality of the telephone lines. This disadvantage

is for the most part nullified when "smart" field interface devices (FID) which report by exception only are used. This type of system does not require the large volume of data transmission that "scanning" EMC systems require. Other problems include lightning protection and maintainability. Maintainability is the major hurdle to the use of all telephone transmission networks. Maintenance problems will primarily occur when an unknown fault occurs in the EMCS. Determining whether the fault is a telephone problem which must be repaired by Base Communications people or an EMCS problem which must be repaired by the EMCS contractor may be very difficult. The success or failure of the use of all telephone data networks will primarily be determined by the personalities involved. If both EMCS contractor, Base Communications, and Base Civil Engineering EMCS operators cooperate, the system should be a success.

In general, all Air Force Bases have remote buildings located a substantial distance from the main concentration of buildings. It is impractical to connect these remote facilities to the EMCS via contractor furnished cable, so telephone transmission must be used for those buildings. Therefore, even though cable may be the primary transmission medium, some telephone transmission is necessary on all installations. The basic design decision relating to transmission system configuration thus becomes a question of how much telephone transmission should be used. At one extreme is the contractor furnished cable system with telephone used only for buildings several miles from the main areas. At the other extreme is the use of government furnished telephone lines to all buildings.

In some cases the decision is made as a matter of policy, while in others it is left up to the designer. The only way to completely evaluate the situation is to configure one transmission system for all telephone and another for contractor cable. Each system is separately run through the prioritization analysis and the results are compared before the decision is made.

If a combined cable and telephone system is decided on, the first step in conceptual design is to lay out the system on a base map. Buildings to be connected to the EMCS must be identified. A rough cable route should be laid out. If the cable is to be installed aerially, existing pole routes must be followed. If the cable is to be direct, buried utilities and pavements should be avoided. Buildings on the extremities of the cable route should be economically evaluated to see whether extending the cable to those buildings would be less expensive than adding a pair of modems to use telephone lines.

Once a proposed network has been configured, a cost estimate must be prepared for each element of the system. The network must be broken down into individual pieces in order for the prioritization analysis to take into account the "geography cost" described in Section 1.5. of this report. A simple way of itemizing each element of the network is through a nodal numbering scheme. A node is placed at each building to be considered for EMCS connection. Additional nodes are placed at any point in the transmission path where data from two or more buildings meet to travel along the same path. These nodes would occur anywhere a branch to a building or buildings occurs in the transmission cable. Each node is assigned a unique identifying number. By estimating the total cost of the data transmission system between each node, the information necessary to perform the prioritization analysis is obtained. Special cases of this approach occur at each building. In addition to the cost of cable from the node at a building to the next upstream node in the data path, the cost of the first field interface device must be added into that element of cost. This is to account for the "connect cost" for that building. If telephone transmission is used for a building, then the node at that building is diagramatically connected directly to the node at the building in which the central control center is located. The cost for this node to node transmission segment is then the cost of the FID in the remote building, plus the cost of a pair of modems for the telephone line.

Once the proposed transmission system layout is complete, the nodal system must be summarized for use in the prioritization analysis.

3.9.1 SUMMARY OF STEPS:

1. Determine criteria or type of transmission media to be employed (all telephone or primarily contractor installed cable).

2. Identify buildings considered for EMCS connection on Base map.

3. Place and number node at each building being considered.

4. If all telephone transmission is to be used, go to step 8.

5. Sketch transmission media routing on Base map according to existing conditions (existing poles, etc.).

6. Analyze extremeties of cable routing for feasibility of cable over telephone use.

7. Place and number node at each branch of the data transmission path.

8. Diagrammatically connect nodes at buildings using telephone transmission to node at central control center.

9. Estimate transmission system cost (cable, poles, trenching, etc.) between each node.

10. Add field interface device cost to node to node section connecting into each building.

11. Tabulate node to node cost data for use in prioritization analysis.

3.9.2 EXAMPLE:

Steps 1 thru 8 above are illustrated on the base map on Figure 74. Steps 9 thru 11 are tabulated on Figure 75.

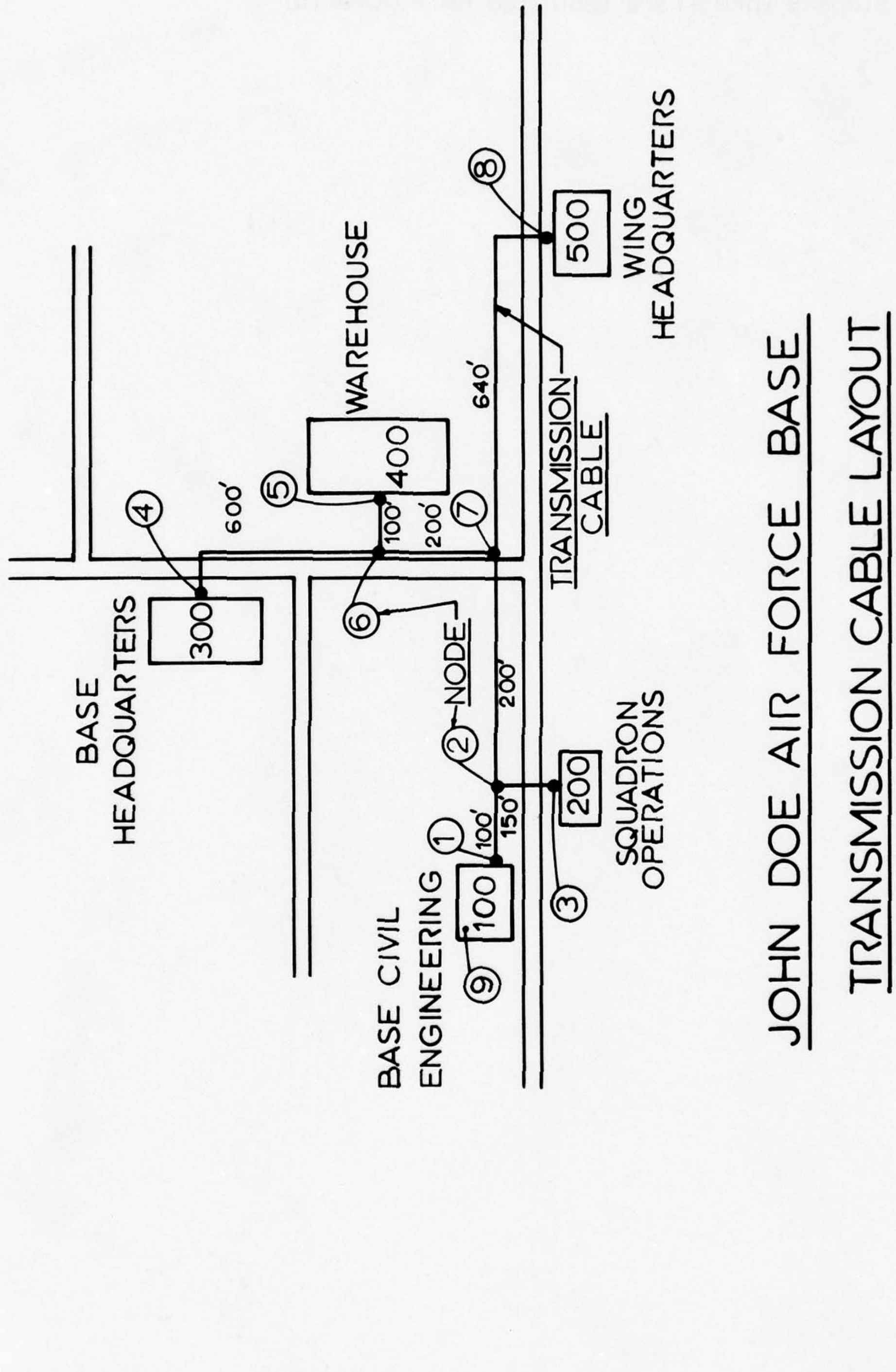

FIGURE 74 - TRANSMISSION CABLE LAYOUT

TRANSMISSION NODAL DATA

NODE	UPSTREAM NODE	LINEAR FEET	\$ CABLE	\$ FID	\$ TOTAL	BUILDING NUMBER
1	0	0	0	0	0	0
2	1	100	500	0	500	0
3	2	150	750	2000	2750	200
4	6	600	3000	2000	5000	300
5	6	100	500	2000	2500	400
6	7	200	1000	0	1000	0
7	2	200	1000	0	1000	0
8	7	640	3200	2000	5200	500
9	1	0	0	2000	2000	100

FIGURE 75 - TRANSMISSION NODAL DATA

3.10 CENTRAL SYSTEM CONFIGURATION

Central System Configuration is the conceptual design of the central EMCS equipment and software and its cost estimation. In addition, related items such as EMCS operator costs, maintenance costs, and training costs are included in the investigation of this area.

3.10.1 SUMMARY OF STEPS

1. List equipment to be contained in the central control center and estimate cost.

2. Estimate cost of annual maintenance contract.

3. Estimate number of operators required and cost.

3.10.2 EXAMPLE:

The central control center costs, maintained costs, and operator costs are shown on Figure 76.

CENTRAL CONTROL CENTER COST

CPU	$ 40,000	
Disk	30,000	
Console	6,000	
Com Mux	5,000	
Printers	8,000	
	$ 89,000	Hardware
Operating System	$ 20,000	
Time Scheduled	15,000	
Optimized S/S	4,000	
Duty Cycling	3,000	
Demand Limiting	3,700	
Enthalpy Control	2,500	
	$ 34,700	Software
TOTAL	$123,700	

(This is unrealistic for a 5 building example so instead use $25,000 for central control center cost.)

MAINTENANCE COST:

Use 5% of total installed cost per year as annual maintenance cost.

OPERATOR COST:

Assume one operator at a cost of $20,000/year.

FIGURE 76 - CENTRAL CONTROL CENTER COSTS, MAINTAINED COSTS, AND OPERATOR COSTS

3.11 PRIORITIZATION ANALYSIS

The Prioritization Analysis is the final ranking of EMCS system functions on a base-wide basis. This analysis takes into account the "geography cost" aspects of the EMCS data transmission network as described in Section 1.5 of this report. The end result of the Prioritization Analysis is a list of all system/functions considered for EMCS connection, ranked from best to worst, based on providing the most savings for the least investment.

Geography cost is accounted for in the final prioritization process. Because geography cost is relevant only on a building by building basis, the system/function prioritization process must also be organized along those lines. The system/functions being considered for EMCS connection must be grouped based on the building in which they occur. For each building, these system/functions are sorted, based on payback period, to form a table for use in the prioritization analysis. After the tables are prepared for each building, the geography cost to connect each building must be estimated. This cost includes all items not directly associated with the performance of a particular function (FID, power supply, transmission cable, etc.) and is calculated, assuming no other buildings are being considered. The geography cost for each building is then combined with the tabulated system/ functions for that building until the best combination (from a payback period standpoint) of system/functions is found for each building. The building with the best combined payback period is then selected to be the first building connected to the EMCS. The best system/function in that building is placed on the top of the prioritized system/function listing. Because parts of the transmission network may be common to several buildings (in the case of contractor furnished transmission cable), the geography cost for each building must be recalculated after each building is connected. The revised geography cost is then used to recalculate a best combined payback period for each building not yet connected to the EMCS. These revised building payback periods are then compared to each other and to the best individual system/functions in buildings already connected, to determine the next system/function to be added

to the prioritized list. This process is repeated until all system/functions in all buildings have been placed on the prioritized list.

3.11.1 SUMMARY OF STEPS:

1. Group and rank functions applicable to systems within each building.

2. Estimate geography cost to connect each building.

3. Combine geography cost with functions for each building until optimum payback configuration is found for each building.

4. Select building with best combined payback period and place top system/function for that building on the prioritized system/function list.

5. Calculate revised geography cost.

6. Repeat steps 3, 4, and 5 until all system/functions have been placed on the prioritized system/function list.

3.11.2 EXAMPLE:

Figures 77 thru 82 illustrate the prioritization calculations for John Doe AFB.

SYSTEM/FUNCTIONS RANKED WITHIN BUILDING

Bldg. #	Sys. #	Sys. Type	Function Number	Cost	Savings	Cumulative Cost	Cum. Savings	Function Payback
100	3	6	1.020323	450	3861	450	3861	0.117
	2	5	1.0302316	450	325	900	4186	1.38
	1	1	14	1150	208	2050	4394	5.5
	3	6	16	250	36	2300	4430	6.9
	1	1	26	250	20	2550	4450	12.5
	2	5	26	250	20	2800	4470	12.5
	1	1	23	300	20	3100	4490	15
	1	1	24	500	20	3600	4510	25
	3	6	24	1000	20	4600	4530	50
	2	5	24	1250	20	5850	4550	62.5
200	2	7	1.030223	450	619	450	619	0.73
	1	14	26	250	20	700	639	12.5
	2	7	8	1320	97	2020	736	13.6
	2	7	16	250	12	2270	748	21
	2	7	24	500	20	2770	768	25
	1	14	24	750	20	3520	788	37.5

FIGURE 77 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

SYSTEM/FUNCTIONS RANKED WITHIN BUILDING

Bldg. #	Sys. #	Sys. Type	Function Number	Cost	Savings	Cumulative Cost	Cum. Savings	Function Payback
300	5	6	1.020323	450	12090	450	12090	0.037
	4	3	1.020323	450	7464	900	19554	0.06
	3	5	1.031623	450	2784	1350	22338	0.162
	6	6	2.0323	450	957	1800	23295	0.47
	6	6	10	3200	2521	5000	25816	1.269
	1	1	14	1150	416	6150	26232	2.8
	2	1	14	1150	416	7300	26648	2.8
	4	3	16	250	72	7550	26720	3.5
	6	6	16	250	72	7800	26792	3.5
	4	3	8	1320	365	9120	27157	3.6
	5	6	16	250	48	9370	27205	5.2
	3	5	12	1150	149	10520	27354	7.7
	1	1	26	250	20	10770	27374	12.5
	2	1	26	250	20	11020	27394	12.5
	3	5	26	250	20	11270	27414	12.5
	1	1	23	300	20	11570	27434	15
	2	1	23	300	20	11870	27454	15
	1	1	24	500	20	12370	27474	25
	2	1	24	500	20	12870	27494	25
	4	3	24	500	20	13370	27514	25
	6	6	24	500	20	13870	27534	25
	3	5	24	750	20	14620	27554	37.5
	5	6	24	1000	20	15620	27574	50

FIGURE 78 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

SYSTEM/FUNCTIONS RANKED WITHIN BUILDING

Bldg. #	Sys. #	Sys. Type	Function Number	Cost	Savings	Cumulative Cost	Cum. Savings	Function Payback
400	2	13	9	1200	1277	1200	1277	0.95
	1	14	26	250	20	1450	1297	12.5
	1	14	24	750	20	2200	1317	37.5
500	1	7	1,020323	450	4442	450	4442	0.1
	1	7	16	250	48	700	4490	5.2
	2	1	14	1150	177	1850	4667	6.5
	2	1	26	250	20	2100	4687	12.5
	2	1	23	300	20	2400	4707	15
	2	1	24	500	20	2900	4727	25
	1	7	24	750	20	3650	4747	37.5

FIGURE 79 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

CONNECT COST/OPTIMUM PAYBACK

BLDG	INITIAL	2ND	3RD	4TH	5TH
			PASS		
100	2000 .635	2000 .635	0 -	0 -	0 -
200	3250 5.98	2750 5.17	2750 5.17	2750 5.17	2750 5.17
300	7500 .397	0 -	0 -	0 -	0 -
400	5000 4.54	2500 2.92	2500 2.92	2500 2.92	0 -
500	6700 1.61	5200 1.27	5200 1.272	0 -	0 -

1. CALCULATE CONNECT COST FROM TRANSMISSION NODAL DATA (FIGURE 9.2).

2. CALCULATE OPTIMUM PAYBACK BY SELECTING THE CUMULATIVE COST (FIGURE 77 THRU 79) WHICH WHEN ADDED TO THE CONNECT COST AND DIVIDED BY THE ASSOCIATED CUMULATIVE SAVINGS GIVES THE LOWEST PAYBACK FOR THE PARTICULAR BUILDING.

FIGURE 80 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

PRIORITIZED SYSTEM/FUNCTION LIST

Bldg. #	Sys. #	Sys. Type	Function Number	Connect Cost	Cumulative* Cost	Cumulative Savings
300	5	6	1.020323	7500	7950	12090
300	4	3	1.020323		8400	19554
300	3	5	1.031623		8850	22338
300	6	6	2.0323		9300	23295
100	3	6	1.020323	2000	11750	27156
300	6	6	10		14950	29677
500	1	7	1.020323	5200	20600	34119
100	2	5	1.03022316		21050	34444
300	1	1	14		22200	34860
300	2	1	14		23350	35276
400	2	13	9	2500	27050	36553
300	4	3	16		27300	36625
300	6	6	16		27550	36697
300	4	3	8		28870	37062
200	2	7	1.030223	2750	32070	37681
500	1	7	16		32320	37729
300	5	6	16		32570	37777
100	1	1	14		33720	37985
500	2	1	14		34870	38162
100	3	6	16		35120	38198
300	3	5	12		36270	38347
500	2	1	26		36520	38367
400	1	14	26		36770	38387
300	3	5	26		37020	38407
300	2	1	26		37270	38427

* DOES NOT INCLUDE CENTRAL EQUIPMENT COST

FIGURE 81 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

PRIORITIZED SYSTEM/FUNCTION LIST

Bldg. #	Sys. #	Sys. Type	Function Number	Connect Cost	Cumulative * Cost	Cumulative Savings
300	1	1	26		37520	38447
200	1	14	26		37770	38467
100	2	5	26		38020	38487
100	1	1	26		38270	38507
200	2	7	8		39590	38604
500	2	1	23		39890	38624
300	2	1	23		40190	38644
300	1	1	23		40490	38664
100	1	1	23		40790	38684
200	2	7	16		41040	38696
500	2	1	24		41540	38716
300	6	6	24		42040	38736
300	4	3	24		42540	38756
300	2	1	24		43040	38776
300	1	1	24		43540	38796
200	2	7	24		44040	38816
100	1	1	24		44540	38836
500	1	7	24		45290	38856
400	1	14	24		46040	38876
300	3	5	24		46790	38896
200	1	14	24		47540	38916
300	5	6	24		48540	38936
100	3	6	24		49540	38956
100	2	5	24		50790	38976

*DOES NOT INCLUDE CENTRAL EQUIPMENT CO–

FIGURE 82 - PRIORITIZATION CALCULATIONS FOR JOHN DOE A.F.B.

3.12 FINAL EMCS CONFIGURATION

Once the prioritized list of system/functions has been prepared, the final EMCS configuration may be determined. The cost to perform each system/function is cumulated along with the central control center cost. Once the cumulated total reaches the maximum budget for the project, system/functions above that point on the list become the final EMCS configuration. System/functions below that point on the list are deleted from consideration. The savings resulting from the system/ functions in the final configuration are totalled to determine the gross annual savings for the EMCS. By subtracting the annual maintenance costs and operator cost from the gross savings, the net annual savings is determined. This figure is divided into the total cumulated cost to determine the overall payback period.

3.12.1 SUMMARY OF STEPS:

1. Add costs (including central control center) of each system/ function on prioritized list until total reaches budget amount.

2. Delete system/functions on prioritized list below the point found in Step 1.

3. Total savings for system/functions remaining on list to obtain gross annual savings.

4. Subtract annual maintenance and operator cost to determine net savings.

5. Calculate overall optimized EMCS payback period using net savings and total construction cost estimate.

6. Proceed with final design of an EMCS configuration including the system/functions on the final prioritized list.

3.12.2 EXAMPLE:

The cumulated cost and overall economic analysis described in Steps 1 thru 5 above are illustrated on Figures 83 and 84.

If the budget for this project is $65,000, up to 65,000-25,000 (Central Equipment Cost) = $40,000 is available for transmission system and field point costs. Given this value the cutoff line may be found as:

PRIORITIZED SYSTEM/FUNCTION LIST

Bldg. #	Sys. #	Sys. Type	Function Number	Connect Cost	Cumulative Cost *	Cumulative Savings
300	1	1	26		37520	38447
200	1	14	26		37770	38467
100	2	5	26		38020	38487
100	1	1	26		38270	38507
200	2	7	8		39590	38604
500	2	1	23		39890	38624
300	2	1	23		40190	38644
300	1	1	23		40490	38664
100	1	1	23		40790	38684
200	2	7	16		41040	38696
500	2	1	24		41540	38716
300	6	6	24		42040	38736
300	4	3	24		42540	38756
300	2	1	24		43040	38776
300	1	1	24		43540	38796
200	2	7	24		44040	38816
100	1	1	24		44540	38836
500	1	7	24		45290	38856
400	1	14	24		46040	38876
300	3	5	24		46790	38896
200	1	14	24		47540	38916
300	5	6	24		48540	38936
100	3	6	24		49540	38956
100	2	5	24		50790	38976

WITHIN BUDGET

OVER BUDGET

*DOES NOT INCLUDE CENTRAL EQUIPMENT COST

FIGURE 82

FIGURE 83 - CUMULATIVE COST & OVERALL ECONOMIC ANALYSIS

From FIGURE 83

Cost:

Central Equipment	=	$25,000
Field Equipment	=	39,890
Total Cost	=	$64,890

Savings:

Total Savings = $38,624/year

Net Savings =

Total Savings - Operator Cost - Maintenance Cost

38,624 - 20,000 - (0.05 x 64,890)

= $15,379/year

Payback Period $= \frac{64,890}{15,379} = 4.2$ years

FIGURE 84 - CUMULATIVE COST & OVERALL ECONOMIC ANALYSIS

4.0 EMCS SKELTON PERFORMANCE SPECIFICATIONS

4.1 INTRODUCTION

The purpose of this section is to develop skeleton performance specifications for EMCS procurement and application. This development has been performed in such a manner that once the information from the identification and prioritization procedures is available and has been verified by field inspection of the functions specified, engineering personnel will be able to select appropriate portions of the specification addressing performance of these functions and prepare a final document appropriate for contract acquisition of an EMCS.

To do this work, a performance specification framework or skeleton has been developed on which actual project specifications may be built. This work does not include the development of a "guide" specification as such. Instead, it outlines items to be included in an EMCS specification and performance approach toward specifying them.

4.2 CONTRACT DOCUMENTS OVERVIEW

Before examining the nature of a performance specification, it is necessary to discuss the role the specification plays in the procurement of an ENERGY MONITORING AND CONTROL SYSTEM (EMCS).

The first stage in the EMCS procurement process is the design phase. The two steps required during this phase are

1) Determine what the EMCS is to do.

2) Prepare contract documents for the procurement of the items defined in step 1.

The first step is the object of primary interest in other volumes of this report. The second step is the primary area discussed in this section.

Once what the EMCS is to do is determined, that information should be translated smoothly into contract document form. These contract documents may then be used to procure the EMCS. Various procurement methods may be used (invitation for bid, request for technical proposal, etc.) but these should have very little effect on the preparation or content of contract documents.

In general, all contract documents must accomplish two tasks. According to the Construction Specifications Institute (CSI), they must

1) Precisely describe design to bidders.

2) Precisely describe design to engineering field representatives.

In addition to these general requirements, EMCS contract documents must

1) Clearly define the EMCS performance requirements.

2) Define specific characteristics, methods, or equipment to be used to meet the performance requirements.

The EMCS performance requirements should be defined before the specific methods or equipment used to accomplish those requirements are determined.

In order to link the analysis procedures discussed in other volumes of this study to the EMCS contract document requirements described above, two primary focal points may be established. Those points are the concepts of EMCS "functions" and energy consuming "systems". These concepts are discussed in Section I of this report. Their definitions are repeated here:

> What an EMCS does is called an EMCS "function". A function is defined as a specific independent operational capability. A function generally consists of several independent activities (data gathering and/or control commanding) linked together by logic to accomplish a specific purpose. Examples of EMCS functions are starting or stopping of equipment based on the time of day, enthalpy based control of an air handler economizer, or reset of a multizone air handler hot deck based on the zone with greatest heating demand. A single function may require the use of several sensors and/or actuators to perform its task. Conversely, it is true that a particular sensor or actuator may be used as a part of the performance of several different functions.
>
> An EMCS performs its functions on "systems". A system, from an EMCS viewpoint, is defined as a group of energy consuming devices which operate together to perform a single common task. Individual items of equipment within a system do not operate

independently of each other. From a control and analysis standpoint, a system will be considered to be completely independent of the operation of any other system. It is important to realize that an EMCS function must be applied to an entire system and not just to a particular item of equipment within that system. For example, if consideration is given only to the operation of a particular motor instead of the system of which that motor is a part, installation and operational problems will occur from improper consideration of local controls, motor interlocks, and other items to which the EMCS must interface to be effective. This also makes effective energy reduction control difficult, and the objective engineering estimation of the savings resulting from that control impossible.

EMCS contract documents must clearly define what each EMCS function is and how it is to be performed. The energy consuming systems to which the functions are to be applied must also be clearly defined along with specifying exactly how each function is installed and operated on a particular system.

Theoretically, a set of contract documents could be prepared for the procurement of an EMCS which would contain only the following:

1) Definition of EMCS functions to be provided

2) Definition of energy consuming systems present

3) Definition of which EMCS functions are to be performed on each energy consuming system present.

This approach has its limitations and in practice would be impossible to implement in its purest form. It does, however, offer a logical means to relate EMCS contract documents to traditional contract documents used in the building industry.

The contract documents used in the building industry traditionally consist of three parts. These are

1) Contractual - Legal Requirements

2) Specifications

3) Drawings.

The first of these parts, the Contractual- Legal Requirements (often referred to as "boilerplate"), would basically be the same for EMCS contract documents as for any other building project. The specifications and drawings for an EMCS project may be related to the basic function and system concepts discussed above.

Because all technical requirements for an EMCS must either be stated on the drawings or in the specifications, some ground rules as to what should be contained in each should be established. Returning to the three items discussed above which theoretically could completely define an EMCS, a simple division between specifications and drawings may be determined. The qualities which make this division possible are that specifications may be relatively portable from one project to the next, while drawings, other than a few standard details, generally are not. The "Definition of EMCS functions to be provided" as part of the theoretical EMCS contract documents would be very similar from project to project and therefore should appear in the specifications. On the other hand, the physical location of energy consuming systems to which those functions are to be applied and the definition of which functions are to be applied to a particular system are unique for each project. These items are logically and most easily included on the drawings.

The purpose of this volume is to develop skeleton performance specifications. Subsequent sections address this in detail. The above discussion has been included primarily to illustrate what is <u>not</u> in EMCS specifications. Although specifications are an important part of the

final set of contract documents, the drawings which correspond to the specification are equally important. They include the detailed requirements for a particular project. A perfect specification may still result in a dismal failure of an EMCS if the specific requirements for the project are not clearly defined on the drawings. The drawings must show exactly what devices are required to perform an EMCS function on a particular type of system (similar to the schematics contained in Section 2 of this report). They must also define the location of each system to be connected to the EMCS, what type of system each is, and what EMCS functions are to be provided for that particular type of system.

One final item should be noted in an overview of EMCS contract documents. That item is the need for contract documents to be definitive. Contract documents for EMCS procurement must fully describe the exact performance required. Although this should be an objective of every set of contract documents, in the past it has not been fully implemented in EMCS procurements because of the nature of past generations of EMCS systems. At one time, an EMCS was available only as a completely packaged system. These systems were inflexible and very difficult to adapt to requirements outside their normal packaged approach. Because of this, contract documents had to be prepared in what could be called a "lowest common denominator" form, i.e., only those functions which were common among several manufacturers could be included. This was because a manufacturer would be eliminated from bidding if a requirement was included which was not a part of his standard package system. A comforting aspect, however, was that, supposedly, the standard package systems provided would have capabilities beyond that called for in the contract documents. This approach is still widely used in the procurement of systems similar to an EMCS. It is no longer valid in the procurement of an EMCS.

With the heavy computerization of EMC systems and the greatly widened competition in the area, flexibility is now much more common throughout the EMCS industry. Both the newer systems houses and the older conventional controls EMCS manufacturers have evolved their

systems to provide much more flexibility, primarily through the use of software. This change from the old packaged EMCS approach has brought about a new problem in the preparation of contract documents. The manufacturers are so flexible now that unless a definitive set of contract documents is provided, they cannot adequately serve the needs of the user. Unless a particular requirement is clearly spelled out in the specifications or on the drawings, that requirement will not be provided for in the EMCS.

There are two approaches to solving this problem. One is to provide a performance requirement for each facet of the EMCS and the other is to take a detailed prescriptive approach to the contract document preparation. These alternatives are discussed in subsequent Sections of this volume.

4.3 NATURE OF PERFORMANCE SPECIFICATIONS

There are two basic classes of specifications:

1) Performance

2) Prescriptive

A performance specification states the results to be achieved. A prescriptive specification describes a means for achieving desired, but normally unstated, ends. Each of these methods has advantages and disadvantages.

In selecting the appropriate method the specifier should answer these questions:

1) What method can best produce the required results?

2) What degree of control must be retained over product selection?

3) How will the choice of method affect final cost?

Each of the specification types offers its own special advantages.

The primary type of prescriptive specification is the descriptive type. A descriptive specification describes in detail the characteristics of a product. It allows the specifier to prescribe exactly what he wants. However, writing a thorough descriptive specification is a time consuming, difficult process, usually resulting in voluminous requirements. High levels of technological proficiency and writing skills are required to produce a thorough descriptive specification. Descriptive specifications tend to increase conflicts between drawings and specifications. The sheer length of a descriptive specification tends to hide omission of essential requirements. Descriptive specifications have a psychological disadvantage compared with shorter forms. By adding to the volume of

material that must be carefully read, descriptive specifications may add costs by increasing the possibility of non-standard items, loopholes, and discrepancies.

A performance specification does not describe the required product; it describes instead what the product must do to be accepted. Performance specifications are difficult to write. They require a thorough understanding of the desired end result. Two key elements in a performance specification are:

1) a definition of each requirement or criterion that the product must satisfy.

2) a corresponding method by which each requirement can be tested.

Performance specifications are ideal for the development of new construction elements or systems. They have little or no advantage in describing packaged systems, except to provide for competition. Performance specifications stimulate competitive bidding. Performance standards promote development of new products or established products for which there are no references.

It is not practical to write a pure performance or pure prescriptive specification. An EMCS specification requires a mixture of the two approaches to achieve success. The performance approach must be the starting point. This is the method with which the EMCS user can usually identify. Through performance specifications, the engineers and technicians in the field can identify and expand on their needs and requirements. Performance specifications are also ideal from the standpoint of encouraging wide competition. On the other hand, the desirable qualities of reliability and standardization for ease of maintenance and non-proprietary expandability, require prescriptive type specifications. It must also be kept in mind that whatever specification is produced must be enforceable to be effective.

Before deciding how much of the specifications should be performance oriented and how much prescriptive, the desired specification characteristics should be defined. This task is undertaken in subsequent Sections of this report.

4.4 DESIRED EMCS SPECIFICATION CHARACTERISTICS

In order to produce an EMCS project specification, certain characteristics and areas should be identified as goals. These goals fall into two general categories. One category is items relative to the specification itself, while the other category is items which relate to the EMCS to be procured with the specification.

The EMCS project specification should have the following qualities:

1) DEFINITIVE

2) ENFORCEABLE

3) UNDERSTANDABLE

4) LOGICAL

5) COMPLETE

6) ACCURATE

7) PRECISE

8) OPEN

The specification should be definitive. It must clearly state and define every desired characteristic or item which the EMCS is to have.

It must be enforceable. It must tell the contractor what shall be done and not leave decisions to the contractor's discretion. The specification should be written with the enforcing authority in mind. If the inspector normally works with plumbing piping, but is required to supervise the EMCS construction, he cannot be expected to enforce specification requirements written for data processing personnel.

The specification should be understandable. Clean, simple, and direct sentences should be used. Words with multiple meanings should be avoided. When reading the specification, the EMCS contractor should not have to interpret the meaning of a sentence based on the context of the particular section of the specifications, paragraph, division, etc.

Logical organization is very important in an EMCS specification. The specification must be logical and easy to follow for all parties involved including base engineers, maintenance engineers, designers, procurement personnel, and, of course, contractor personnel.

A complete specification is needed for EMCS procurement. Specifications must cover all aspects of the EMCS. The specifications should not concentrate on a particular area in great detail while leaving other areas undefined or unclear.

The specification should be accurate. If a publication or standard is referred to, the exact and current name and number should be referred to.

The specification should be as precise as possible. Exact numerical requirements should be stated wherever possible. Phrases such as "adequate quantity" should be avoided.

Finally, the specification should be "open" from a bidder's standpoint. Requirements which unnecessarily restrict competition should not be included. The maximum number of manufacturers should be encouraged to bid.

Besides the characteristics of the specification listed above, there are certain highly desirable characteristics of the EMCS which should also be kept in mind. These are:

1) CONSERVE ENERGY

2) MAINTAINABLE

3) ACCURATE

4) EXPANDABLE

5) RELIABLE

6) USABLE

7) MINIMIZE COST

Above all other considerations, the purpose of the EMCS must be kept in mind. That purpose is to conserve energy. In deciding which requirements to include during the EMCS project specification production, the specification writer must always first ask himself "Does it save energy?".

The EMCS must be maintainable. It must contain self-diagnostic functions to isolate failures of individual components. Once the failure is isolated, the component must be easily replaceable or repairable. The EMCS should be as simple as possible to reduce maintenance problems. The EMCS should be accurate. Laboratory precision is not needed but reasonable, repeatable accuracy is a necessity. The system must gain the confidence of its operators and users if it is to be effective. False signals and inaccurate readings do not gain confidence.

Expandability is a major problem in EMCS procurement. It is highly desirable that the expansion of an existing EMCS be competitively bid. This can only be controlled by action in the design and installation of the original system. If not properly handled at that stage, the expansion of the system may have to be through a sole source procurement contract with the original system manufacturer. Past experience indicates this to be an expensive proposition compared to a competitive bid situation.

Reliability, like accuracy, is very important to the gaining of operator and user confidence. If the EMCS spends a substantial amount of time in an inoperative condition, the user cannot learn to rely on the EMCS and thus will not use its capabilities in the most effective manner.

Another area requiring consideration is that of EMCS usability. The EMCS must be easily operated and available personnel must be able to perform at least basic tasks with a minimum of training. Overwhelming a user with complicated capabilities he is not able to use can have the same disintegrating effect on confidence as inaccurate readings or extended down time.

Of course, the final judgement of any item is in its cost. Every item which goes into an EMCS should be evaluated for its effect on overall cost of the system. Items that may be desirable from an accuracy, reliability, usability, etc., standpoint may drastically affect prices, particularly when dealing in areas not commonly available in commercial, standard, EMC systems.

4.5 APPROACH

The first step in the development of a skeleton EMCS performance specification is to define an EMCS as a "black box". Theoretically, a pure performance specification would define all the inputs and outputs to that black box and say nothing about what is required inside the box. This is a starting point in the development of an EMCS specification. Before thinking about the inputs and outputs to the box, its boundaries must be established. The widest possible borders are chosen to make the approach as general as possible. These boundaries are the operator on one end and the energy consuming systems being monitored and controlled on the other. Everything between those two points belongs in the black box labeled EMCS.

Note that four data flow paths exist across the black box boundaries. Two of the paths transfer data into the EMCS. These are:

1) Operator Commands

2) Monitored System Data

The other two paths transfer data out of the EMCS. These are:

1) Display Operator Information

2) System Control Actions

It would seem a simple task to define each of these four data paths and thus have a complete EMCS performance specification. This is not the case. What happens within the black box is more than just a simple relationship between input data and output data. The logic within the black box can be and is quite complicated. The logic within the black box in fact is what makes it an EMCS.

In order to specify an EMCS, the logic within that black box must be specified in addition to the data paths crossing the box boundary. An EMCS contains many input-logic-output paths. Each of these paths must be defined in order to specify EMCS performance. EMCS performance should be defined before any discussion of what hardware or software is needed to accomplish that performance.

Two basic types of input-logic-output paths occur in an EMCS. These are:

1) Applications

2) Operations

The applications logic paths are those that are directly related to the purpose of an EMCS, to conserve energy. An appropriate label for these paths is that of "application functions". This term has been used in other volumes of this report and provides a link between the performance specification of an EMCS and the analysis techniques developed under this study.

The operations logic paths are those not directly related to energy conservation but necessary to the support of the applications functions and the operation of the EMCS itself. These paths will be referred to as "operations features" of an EMCS.

By specification of all applications functions and operations features, along with their associated data paths, an EMCS can be totally defined from a performance standpoint. A pure EMCS performance specification would define those two areas and that is all.

Practically, a pure performance specification is not possible, some prescriptive requirements must occur in an EMCS specification. These requirements are needed to assure EMCS maintainability, expandability, reliability, and usability. The prescriptive requirements should only be included to obtain these qualities and should not restrict the use of new or different approaches and technology.

In addition, standard general requirements must accompany any construction specification regarding shop drawings, schedules, verification of dimensions, other contract documents, etc. These requirements must be defined in a separate section of the specification.

Thus it would appear the EMCS specification would logically be divided into four sections. One section would contain standard general paragraphs, two sections would contain performance requirements for applications functions and operations features, and the final section would contain prescriptive requirements defining particular items of equipment, software, or methods to be used. This last section defines the EMCS configuration.

In summary, the approach to be used for an EMCS skeleton performance specification will be to develop the specification around the following sections:

1) GENERAL

2) EMCS APPLICATIONS FUNCTIONS

3) EMCS OPERATIONS FEATURES

4) EMCS CONFIGURATION

4.6 EMCS PERFORMANCE SPECIFICATION OUTLINE

The primary purpose of this volume is to develop a skeleton EMCS specification. To accomplish this, an outline of topics to be covered under each of the four specification sections discussed in Section 5.0 has been prepared. This outline provides a framework around which the EMCS design engineer may build a performance oriented specification for a particular project. Items listed in the outline are described and discussed in Section 4.7 of this Volume.

The intent of the information contained herein is not to provide a "guide specification" for immediate use in EMCS procurement. Instead, a method for preparing a performance oriented EMCS specification which is compatible with the analysis techniques developed under this study is presented. Examples of specification sections prepared according to this approach are included in APPENDIX AI. These examples should not be used directly as a guide, they have been prepared strictly for illustrative purposes. The preparation of a final project specification ready for bidding will require detailed investigation of all areas of the specification. This investigation must be carried out on an individual project basis and is beyond the scope of this investigation.

The EMCS PERFORMANCE SPECIFICATION OUTLINE is contained on the following pages:

ENERGY MONITORING AND CONTROL SYSTEM

PERFORMANCE SPECIFICATION OUTLINE

DIVISION 13

13.1	GENERAL
13.1.1	APPLICABLE PUBLICATIONS
13.1.2	SCOPE OF WORK
13.1.3	WORK SPECIFIED IN OTHER DIVISIONS
13.1.4	OTHER CONTRACT DOCUMENTS
13.1.5	SINGLE SOURCE RESPONSIBILITY
13.1.6	MANUFACTURER'S DATA
13.1.7	PRODUCTS
13.1.8	DELIVERY AND STORAGE
13.1.9	MANUFACTURER'S RECOMMENDATIONS
13.1.10	VERIFICATION OF DIMENSIONS
13.1.11	SAFETY REQUIREMENTS
13.1.12	WELDING
13.1.13	WIRING

13.1.14 CONSTRUCTION DAMAGE

13.1.15 NAMEPLATES

13.1.16 CONTRACT PERFORMANCE PERIOD

13.1.17 EXISTING CONTROLS

13.1.18 TESTING

13.1.19 TOOL AND SPARE PARTS LISTS

13.1.20 MAINTENANCE MANUALS

13.1.21 WARRANTY

13.1.22 MAINTENANCE CONTRACT

13.1.23 TRAINING

13.1.24 ABBREVIATIONS AND DEFINITIONS

13.2 EMCS APPLICATIONS FUNCTIONS

13.2.1 DEFINITION

13.2.2 TIME SCHEDULED OPERATION

13.2.3 DUTY CYCLING

13.2.4 ELECTRICAL DEMAND LIMITING

13.2.5 WARM UP/NIGHT CYCLE

13.2.6 ENTHALPY ECONOMIZER

13.2.7 SPACE NIGHT SETBACK

13.2.8 HOT/COLD DECK RESET

13.2.9 CHILLED WATER RESET

13.2.10 CONDENSER WATER RESET

13.2.11 OUTSIDE AIR SCHEDULE RESET

13.2.12 START/STOP OPTIMIZATION

13.2.13 BOILER PROFILE AND OPTIMIZATION

13.2.14 CHILLER PROFILE AND OPTIMIZATION

13.2.15 MAINTENANCE RUN TIME REPORTING

13.2.16 TROUBLE DIAGNOSIS

13.2.17 CRITICAL AREAS MONITORING

13.2.18 EXTENDED SERVICE CONTROL

13.3 EMCS OPERATIONS FEATURES

13.3.1 DEFINITION

13.3.2 EMCS STARTUP AND SHUTDOWN

13.3.3 DATA GATHERING

13.3.4 ACCESS CONTROL

13.3.5 MULTIPLE OPERATOR ACCESS

13.3.6 OPERATOR ASSISTANCE

13.3.7 DISPLAY

13.3.8 MANUAL CONTROL

13.3.9 ALARMS

13.3.10 REPORTS

13.3.11 ADDITIONS AND MODIFICATIONS

13.3.12 CONTROL SEQUENCES

13.3.13 SELF DIAGNOSIS

13.3.14 PARTIAL FAILURE

13.3.15 ORDERLY SHUTDOWN

13.3.16 POWER INTERRUPTION

13.4 EMCS CONFIGURATION

13.4.1 CONFIGURATION OVERVIEW

13.4.2 CENTRAL EQUIPMENT

13.4.3 FIELD EQUIPMENT

13.4.4 SOFTWARE

13.4.5 SIGNAL TRANSMISSION

4.7 OUTLINE SPECIFICATION DESCRIPTION

To use the specification outline presented in the previous section this volume, a brief description of each of the elements of the outline has been prepared. These descriptions provide minimal explanation and guidance to the EMCS designer in the research necessary to turn the skeleton EMCS performance specification into a final specification. The description is as follows:

13.1 GENERAL: This section should contain all elements of the specification not directly related to a particular EMCS application function or operations feature, and which do not directly describe the particular EMCS configuration desired. Standard construction paragraphs from Corps of Engineers or NAVFAC guide specifications should be included in this section.

13.1.1 APPLICATION PUBLICATIONS: This paragraph should contain accurate and current listings of standards and publications referred to later in the specification. Only items referred to later should be listed here. This paragraph should be broken into subparagraphs with each subparagraph containing the name, number and data for publications by a particular group or standards authority.

13.1.2 SCOPE OF WORK: All specifications require some description of the work to be done on a particular project. This paragraph should be used to describe the magnitude of the particular project to the potential bidder. This paragraph should not be used to convey particular requirements. Unless those requirements are specified or shown elsewhere in the contract documents in detail, listing them only under the SCOPE OF WORK paragraph will probably be unenforceable.

13.1.3 WORK SPECIFIED IN OTHER DIVISIONS: Work not specified in this division but included in the project should be referred to here. Installation of ductwork, dampers, thermometer wells, etc., is normally part of Division 15. Installation of conduit, wiring, power circuits, poles, etc., is normally part of Division 16. These should be referenced in this paragraph.

13.1.4 OTHER CONTRACT DOCUMENTS: A list of other contract documents besides the specification should be referred to here. These include contract drawings, reference drawings, I/O Summaries if provided separately, schematics, etc. Enough information should be indicated (beginning drawings numbers, ending drawing numbers, etc.) such that the bidder may determine whether or not he has received a full set of contract documents.

13.1.5 SINGLE SOURCE RESPONSIBILITY: Because it is common for EMCS contractors to build systems by piecing together components purchased from various manufacturers, it should be made clear that the EMCS contractor is personally responsible for the total system and all its components. The government must only deal with one contractor, any trouble that arises from component failure must be between the EMCS contractor and that component's manufacturer.

13.1.6 MANUFACTURER'S DATA: This paragraph should contain required submittal data, shop drawings, control diagrams, standards compliance certificaton, etc. In some situations, these items are listed in Division 1 and should not be repeated in Division 13. In either case, the list should be prepared by the EMCS designer and a reasonable schedule for submittals must be included.

13.1.7 PRODUCTS: Standard paragraph stating materials and equipment shall be the latest standard catalogued products of a manufacturer regularly engaged in the production of such materials and equipment.

13.1.8 DELIVERY AND STORAGE: Standard paragraph stating materials and equipment shall be delivered and stored as recommended by the manufacturer and as approved by the Contracting Officer.

13.1.9 MANUFACTURER'S RECOMMENDATIONS: Standard paragraph stating items shall be installed according to the manufacturer's recommendations.

13.1.10 VERIFICATION OF DIMENSIONS: Standard paragraph on contractor familiarization with the site and notification of the contracting officer of conflicts found.

13.1.11 SAFETY REQUIREMENTS: Standard paragraph.

13.1.12 WELDING: Standard welder qualifications paragraph.

13.1.13 WIRING: Standard paragraph on wiring with reference to Division 16.

13.1.14 CONSTRUCTION DAMAGE: Standard paragraph on repair of damage.

13.1.15 NAMEPLATES: This paragraph should define on what items nameplates are required, what material the nameplate should be made of, and what should be written on the nameplate.

13.1.16 CONTRACT PERFORMANCE PERIOD: This paragraph should refer to the schedule in the legal portion of the specification and should be used to define what is to take place in the time span listed (i.e. whether or not the operational testing period is included in the scheduled time or follows it etc.).

13.1.17 EXISTING CONTROLS: This paragraph should define the EMCS contractor's relationship to the existing control systems. It should carefully define what he is or is not responsible for. It may be easier to define this point on control or system schematics if these are used on the drawings for a particular project. This is a critical paragraph which can unintentionally add thousands of dollars to an EMCS project or can result in an unoperational EMCS if not handled properly. The decision as to just what is required in this paragraph can only be made after inspection of existing controls and in light of just which EMCS functions are to be provided. Generally simple start/stop controls of systems does not prove particularly difficult. However, more complicated optimization functions which must interface

with existing controls and which depend on the proper operation of those local controls present a much more complicated problem.

13.1.18 TESTING: This paragraph should cover all testing of the EMCS. Three tests are commonly considered:

1) FACTORY TEST
2) FIELD TEST
3) FINAL OPERATIONAL TEST

Factory Tests require the setup at the EMCS contractor's facility of all central control center equipment and software connected to typical FID configurations via each of the different types of data transmission links. Each of the FID's should be connected to at least one of every type of sensor or controller to be used. This sample EMCS is used to demonstrate the performance of the system according to the specifications to the Contracting Officer before shipment of central control center equipment or FID's to the project site.

The FIELD TEST should consist of a detailed demonstration of every element of the EMCS following installation.

The FINAL OPERATIONAL TEST usually consists of a 30 day period following the field test in which the EMCS operates at or above a certain specified operational level.

13.1.19 TOOL AND SPARE PARTS LISTS: Standard paragraph requiring the contractor to provide a list of spare parts and special tools relevant to the EMCS.

13.1.20 MAINTENANCE MANUALS: Manuals containing maintenance requirements for every component of the EMCS should be defined in this paragraph.

13.1.21 WARRANTY: Warranty requirements and duration should be carefully specified.

13.1.22 MAINTENANCE CONTRACT: If a full or partial maintenance contract is to be provided by the EMCS contractor, the terms and duration of that agreement must be spelled out in detail.

13.1.23 TRAINING: The duration, type, and time of occurrence of all training should be defined. Training requirements will vary widely depending on the type and size of the EMCS. The approach to manning the EMCS by the owner should also be considered when writing these requirements into the EMCS specifications.

13.1.24 ABBREVIATIONS AND DEFINITIONS: If words or phases are used in the specification which have specific meanings not in everyday vocabulary, they may be defined under this paragraph.

13.2 EMCS APPLICATIONS FUNCTIONS: This section of the specifications should be used to spell out the performance of the EMCS in regards to energy conservation activities. Examples of the performance specification of applications functions are included in the APPENDIX. The general organization used to specify each application function has been to include the following paragraphs:

1) DEFINITION
2) OPERATION
3) SYSTEMS INTERFACE
4) OPERATOR INTERFACE
5) RELATIONSHIP TO OTHER APPLICATION FUNCTIONS
6) FAILURE MODE

A DEFINITION of each applications function is usually required to avoid terminology differences in the EMCS industry.

The OPERATION paragraphs should describe the logic by which a particular application's function is performed. In addition, capacity requirements should be defined for functions which require variable quantities of data for definition of the function. For example, the minimum number of different schedules and different types of sche-

dules which the EMCS must maintain in performing time scheduled operation of equipment must be defined.

The SYSTEM INTERFACE paragraphs should define the specific input and output data necessary for the performance of the application function on an energy consuming system.

The OPERATOR INTERFACE paragraph should define the operator's ability to change parameters relevant to the particular application function along with specific displays required.

The RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS paragraphs must define any hierarchal relationships to be maintained wherever two applications functions are applied concurrently to the same energy consuming system.

The FAILURE MODE paragraph should define what should happen to an energy consuming system currently being controlled by an EMCS applications function on failure of the EMCS. The most common approach is to return the system to local control, however, that approach may not be adequate for all EMCS functions.

13.2.1 DEFINITION: A definition of EMCS application functions and discussion of the performance requirements stated therein relative to the rest of the specification should be included.

13.2.2 TIME SCHEDULED OPERATION

Time scheduled operation consists of the starting and stopping of a system based on the time and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. This is the simplest of all EMCS functions to install, maintain, and operate. It also provides the greatest potential for energy conservation if systems are currently being unnecessarily operated during unoccupied hours.

13.2.3 DUTY CYCLING

Duty cycling consists of the shutdown of a system for predetermined short periods of time during normal operating hours. This function is normally only applicable to heating, ventilating, and air conditioning systems. Its operation is based on the theory that HVAC systems seldom operate at peak output, thus if the system is shutoff for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during this shutdown. Although the interruption does not reduce the net space heating or cooling energy, it does reduce energy input to constant auxiliary loads such as fans and pumps. This function also reduces outside air heating and cooling loads since the outside air intake damper is closed while an air handling unit is off. Systems are generally cycled for some fixed period of time, say 15 minutes, out of each hour of operation. The off period time length and its frequency should be adjustable. The off period time length is normally adjusted for a longer duration during moderate seasons and shorter duration during peak seasons.

13.2.4.1 DEMAND LIMITING START/STOP:

This function consists of the stopping of electrical loads to prevent setting a high electrical demand peak and thus increasing electrical costs where demand oriented rate schedules apply. Many complex schemes exist for accomplishing this function. In general, they all continuously monitor the base electrical demand. Based on the monitored data, demand predictions are made by the EMCS. When these predictions exceed preset limits, certain scheduled electrical loads are shut off by the EMCS to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the function requirements. Generally, the loads to be shed are HVAC items. The reasoning used in the Duty Cycling discussion holds here also: allow a slight temperature drift in the space by shutting off the HVAC equipment.

13.2.4.2 DEMAND LIMITING, GENERATOR OPERATION:

This function is actually a part of the program that controls the DEMAND LIMITING, START/STOP function. In fact, the only difference between the two functions is that the previous function stopped equipment to reduce demand and this function starts equipment for the same purpose. This function is only applicable where large standby generators are existing. When electrical demand approaches a peak, this function starts the engine or turbine generators which feed electrical power into the building where they are located, or drive specific items of equipment such as well water pumps, thus reducing base electrical demand. Extreme caution must be exercised in using this function. Only the largest of generators should be considered because considerable investigation and expense may be necessary to perform any rewiring or reswitching needed for proper operation of this function.

13.2.4.3 DEMAND LIMITING, CHILLER LIMIT ADJUST:

Centrifugal water chillers are generally equipped with a manually adjustable control system which limits the maximum current, and thus power, the machine may use. An interface between the EMCS and this control circuit allows the EMCS to reduce the limit setting in a load shedding situation and thus reduce the electric demand without completely shutting down the chiller. The method of accomplishing this function varies with the specific manufacturer of both the water chiller and the EMCS. The principle of operation is the same, however. When the chiller is selected for load shedding, a single stop signal is transmitted to the interface which then reduces the chiller limit adjustment by a fixed amount. Normally, the actual setting of the chiller limit adjust is not resetable or even detectable from the EMCS. Extreme caution must be exercised with application of this function. Incorrect interface and control can cause the refrigeration machine to operate in a surge condition, ultimately causing considerable damage to the equipment.

13.2.5 WARM UP/NIGHT CYCLE:

The thermal load imposed by outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements for a facility, depending on the geographical location. This function can control the outside air dampers when the introduction of outside air would impose a thermal load and the building is unoccupied. This function would apply during warm up or cool down cycles before occupancy of the building and would also apply in certain facilities that require maintenance of environmental conditions for proper operation of electronic equipment, although the building is unoccupied. During those times, the outside air dampers would be closed.

13.2.6 ENTHALPY ECONOMIZER:

The use of an all outside air economizer cycle can be a cost effective energy conservation measure, depending on the climatic conditions and the type of mechanical system. Where applicable, the cycle utilizes outside air to satisfy all or a portion of the building's cooling requirements when the enthalpy or total heat content of the outside air is less than that of the return air from the space. Outside air is introduced through the mechanical system and relieved during this cycle in lieu of the normal recirculation system.

13.2.7 SPACE TEMPERATURE NIGHT SETBACK:

The energy required to maintain space conditions during the unoccupied hours can be reduced by lowering the temperature set point for the space, depending on the climatic conditions. This function also would apply only to facilities that are not required to operate 24 hours per day. Normally, where applicable, this function would reduce the space temperature from the normal 68° winter inside design temperature to a 50° or 55° space temperature during the unoccupied hours.

13.2.8 HOT/COLD DECK TEMPERATURE RESET:

Mechanical systems such as dual duct systems and some multizone systems use a parallel arrangement of heating and cooling surfaces commonly referred to as hot and cold deck surfaces for the purposes of providing heating and cooling mediums simultaneously. Generally speaking, both heated and cooled air streams are mixed to satisfy the individual space thermal requirements. In the absence of optimization controls, these systems can be very wasteful from an energy standpoint because the final space control merely mixes the two air streams to produce the desired result. While the space conditions may be acceptable, the greater the difference between the temperatures of the two streams, the more inefficient the operation will be . This function can select the individual areas with the greatest heating and cooling requirements, establish the necessary hot deck and cold deck temperatures based on these extremes, and, as a result, minimize the inefficiency of the system.

13.2.9 CHILLED WATER RESET:

The energy required to generate chilled water in a reciprocating or centrifugal electric driven refrigeration machine is a function of a number of parameters including the temperature of the chilled water leaving the machine. Because the refrigerant suction temperature is a direct function of the leaving water temperature, the higher the two temperatures, the lower the energy input per ton of refrigeration. As a result, because chilled water temperatures are selected for peak design times, in the absence of strict humidity control requirements, most chilled water temperatures can be elevated during most operating hours. Depending on the operating hours, size of the equipment, and configuration of the system, energy savings can be effected by resetting the chilled water. Similar to the previously described reset function, the chilled water temperature can be elevated to satisfy the greatest cooling requirements. Generally, this determination is made by the position of the chilled water valves on the various cooling

systems. The positions of the control devices supplying the various cooling coils are monitored and the chilled water temperature is elevated until at least one control device is in the maximum position. Other control schemes may be necessary to satisfy different system configurations.

13.2.10 CONDENSER WATER TEMPERATURE RESET:

Another parameter affecting the energy input to a refrigeration system is the temperature of the condenser water entering the machine. Conventional heat rejection equipment is designed to produce a specified condenser water temperature such as 85° at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain a specified temperature at conditions other than peak design. To optimize the performance of the condenser water system, however, this system can be reset when outdoor wet bulb temperatures will produce lower condenser water temperature. Where applicable, this function will reduce the energy input to the refrigeration machine.

13.2.11 OUTSIDE AIR TEMPERATURE RESET SCHEDULE:

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are designed to supply the heating requirements for the system at outdoor design temperatures. Frequently, depending on the specific system design, the hot water supply temperature can be reduced as the heating requirements for the facility are reduced. For most facilities, this reduction in heating requirements is directly related to an increase in outdoor ambient temperature. Where applicable, the capability to reduce the temperature of the supply water as a function of outdoor temperature will affect operating savings. To accomplish this function, the temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature.

13.2.12 START/STOP OPTIMIZATION:

An additional feature of the time scheduled operation of mechanical systems described above is the optimized start/stop feature available from the system. Mechanical systems serving areas that are not occupied 24 hours a day should be shut down during the unoccupied hours. Traditionally, the systems are restarted prior to occupancy in order to cool down or heat up the space. Normally this function is performed on a fixed schedule independent of weather, space conditions, etc. The optimized start/stop feature of the system automatically starts and stops the system to minimize the energy required to provide the desired environmental conditions during occupied hours. The function automatically evaluates the thermal inertia of the structure, the capacity of the system to either increase or reduce temperatures in the facility, start-up and shut-down times, and weather conditions to accurately determine the minimum hours of operation of the HVAC system to satisfy the thermal requirements of the building.

13.2.13 BOILER PROFILE AND OPTIMIZATION:

In certain application of multi-boiler central heating plants, the opportunity exists for optimization of the boiler plant through selection of the most efficient equipment to satisfy the instantaneous heating requirement. By monitoring fuel input as a function of the output, profiles can be developed for each of the units in a central plant. Based on the operating history developed, and the loads, plant operation can be optimized to minimize energy input.

13.2.14 CHILLER PROFILE AND OPTIMIZATION:

This function is very similar to the boiler profile described above. Operating data is obtained and compared with the predicted operating characteristics of each individual machine prepared by the manufacturer. Based on the operating data for each machine with the energy input requirements for each operating condition and the instantaneous

load, the function would select the chiller or chillers required to meet the load with the minimum energy input.

13.2.15 MAINTENANCE RUN TIME REPORTS:

A number of maintenance functions associated with mechanical equipment are related to or can be related to the number of operating hours of the specific item of equipment. Some of these functions include lubrication, cleaning, bearing checks, etc.

13.2.16 TROUBLE DIAGNOSIS:

By monitoring certain parameters of the mechanical/electrical systems, diagnosis of reported problems with mechanical and electrical systems can be performed at the central console location. Some of the parameters that might be monitored for the purposes of trouble diagnoses include hot and cold deck temperatures with high and low limits, leaving chilled water temperatures and hot water temperatures with high and low limits, differential pressure switches indicating fan and pump operation, and space temperatures.

13.2.17 CRITICAL AREAS MONITORING:

Areas such as electronic data processing equipment rooms, test facilities, environmental test rooms, and other areas with critical requirements for environmental control can be monitored for status and alarm indication.

13.3 EMCS OPERATIONS FEATURES: This Section is concerned primarily with the performance specification of EMCS activities and capabilities that are not directly related to conserving energy. These features are essential to the normal and effective operation and use of the EMCS. These features are primarily related to the external "appearance" of the EMCS and its relationship to its operator.

13.3.1 DEFINITION: A brief definition of operations features and their relationship to the rest of the EMCS should be included.

13.3.2 EMCS START UP AND SHUTDOWN: Requirements describing the EMCS performance on start up and shutdown should be included here. Start up requirements such as complete initiation from a single key input should be defined.

13.3.3 DATA GATHERING: Required performance of the EMCS in its data gathering operations should be defined. Items to be specified should include rate of monitoring each data sensor and "end-to-end" accuracy of EMCS data gathering. "End-to-end" accuracy refers to a comparison of the actual value of the measured variable (one "end") to the value displayed by the EMCS at the central control center (the other "end").

13.3.4 ACCESS CONTROL: A system should be specified which protects the EMCS from unauthorized access. This normally is done through a hierarchal password entry system.

13.3.5 MULTIPLE OPERATOR ACCESS: Sometimes a particular EMCS project will require multiple simultaneous operator access. The number of concurrent separate operator activities the EMCS must be able to handle and the nature of those activities should be specified.

13.3.6 OPERATOR ASSISTANCE: A common EMCS feature is a provision for prompting the operator on the use of the EMCS. This assistance may consist of a listing of the possible commands the EMCS will accept from the operator, or it might include a list of all buildings and systems connected to the EMCS. The desired capabilities of this feature should be fully specified.

13.3.7 DISPLAY: The operation and interaction of the EMCS display should be performance specified as completely as possible. The method of "addressing" should be defined. "Addressing" is the means of displaying the status of a particular point or group of

points. One logical addressing scheme is the use of a three level identification for every sensor and controller. The first level is the building number in which the point occurs, the second level is the system number in which the point occurs, and the third level is an identifier unique to the particular device. Another area of particular importance is the use of any graphics systems in the system operation. Exactly how the graphics are to be used, when they are to be displayed, and what they are to display should be defined. Other simpler minimum requirements for items such as the range of a temperature display (say - 99.9 to 999.9) and the units (°F) might be identified.

13.3.8 MANUAL CONTROL: The capabilities to be provided for direct operator control or override should be specified under this heading.

13.3.9 ALARMS: Conditions under which the EMCS should provide alarms and the method of reporting each type of alarm should be defined.

13.3.10 REPORTS: Reports to be provided by the EMCS should be defined in accordance with the requirements of the particular EMCS project. Reports might include listings of all points connected to the EMCS, parameters associated with each point, and the current status of each point. Other reports might be logs of the previous days electrical profile, run times on each system, current and past alarms, etc.

13.3.11 ADDITIONS, MODIFICATIONS AND DELETIONS: The means and ability to add additional points to or delete points from the EMCS and method of modification of parameters present in the EMCS should be defined.

13.3.12 CONTROL SEQUENCES: Features allowing the interlocking of various systems, thru EMCS control, along with the ability to construct control sequences which react to various input parameters must be fully specified if desired.

13.3.13 SELF DIAGNOSIS: The extent of the ability to isolate and indicate which components have failed on trouble occurrence within the EMCS should be described.

13.3.14 PARTIAL FAILURE: On partial failure of the EMCS, the sequence of events that is desired should be specified. For instance, if a particular printer fails, its activity should be automatically diverted to another printer. This should be described in the specification to assure proper performance of the EMCS under those conditions.

13.3.15 ORDERLY SHUTDOWN: The sequence of events necessary to provide for orderly shutdown of the EMCS should be specified. On a power failure for example, the operating status of the EMCS should be retained and no damage should occur.

13.3.16 POWER INTERRUPTION: If special provisions are to be made in the event of power interruption to the EMCS, these should be specified under this heading. Topics which might be covered include battery backup, uninterruptable power supplies, and switchover to emergency generator.

13.4 EMCS CONFIGURATION: This section is used to specifically define hardware and software required for a particular EMCS project. The detail and extent of this section will be dependent on the requirements and philosophy of the EMCS designer and the final user of the system. A relatively simple and abridged section can be written which, when combined with Sections 13.2 and 13.3, will produce an overall performance oriented specification. On the other hand, if a prescriptive specification is desired, this may be obtained by very detailed requirements in this section. A section written in this manner would be combined with Section 13.2 and 13.3 to produce an overall specification which not only defines the performance required from the EMCS but also how that performance is to be done.

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ENERGY MONITORING AND CONTROL SYSTEM (EMCS) APPLICATION STUDY. --ETC(U)
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An advantage of having the EMCS CONFIGURATION requirements separated from the applications and operational performance requirements is that the specification can be easily adapted to changes and advancements in technology. This approach also allows the use of different design philosophies within the Air Force without adverse impact on the performance requirements of the EMCS.

13.4.1 CONFIGURATION OVERVIEW: A descriptive overview of the required EMCS configuration should be provided. This overview should briefly describe the general operation and requirements of the central control center, the transmission system, the field interface devices and the sensors and controls. An overview schematic of the EMCS configuration should be provided on the contract drawings.

13.4.2 CENTRAL EQUIPMENT: These paragraphs should define the equipment to be located in the central control center. Some items which may or may not be included are:

1) Central Communications Controller (CCC).
2) Central Processing Unit (CPU).
3) Maintenance and Control Panel.
4) Real-Time Clock (RTC).
5) Disk Storage Systems.
6) Floating Point Processor.
7) External Uninterruptible Clock.
8) Auxiliary Power Supply.
9) Printers (all types).
10) CRT Systems (Controllers, Displays, and Keyboards).
11) Paper Tape Reader/Punch.
12) Magnetic Tape Drives
13) Remote Dial Up Interface

13.4.3 FIELD EQUIPMENT: These paragraphs should define the equipment to be used in buildings to be connected to the EMCS. Items to be covered under these paragraphs might include:

1) Field Interface Devices
2) Multiplexer Panels
3) Function Cards
4) Sensor and Control Devices

13.4.4 SOFTWARE: Specific software requirements should be defined under this heading. These requirements should be carefully related to the performance requirements of Sections 13.2 and 13.3. Topics which might be included under this heading are:

1) Bootstrap Program
2) Real-Time Disk Operating System/Executive (RTDOS/E)
3) Assembler
4) Relocatable Linking Loader
5) Editor
6) FORTRAN Compiler
7) BASIC Compiler and/or Interpreter
8) Debugger
9) Copy Routine
10) Dump Routine
11) Disk Routine
12) Mathematics Package
13) CCU Diagnostic Programs
14) Command Line Mnemonic Intrepreter
15) CLM Commands
16) Report Generator
17) Index
18) Graphic Software
19) Control Sequence Software
20) Alarms
21) Peripheral Device Sharing
22) Operator Control Software
23) Predictor/Corrector Program
24) System Access Control
25) FID Software Editing

13.4.5 SIGNAL TRANSMISSION: Specific materials, methods, and equipment to be used in the EMCS data transmission network should be defined under this heading. Both the signals to be transmitted and the media over which they are transmitted may be defined. Items in this area include:

1) Signal Transmission Interface
2) Signal Error Detection and Retransmission
3) Signal Error Rate
4) Government Furnished Lines
5) Transmission Media
6) Modems
7) Cable Installation
8) Grounding and Lightning Protection

APPENDIX

1.0 TIME SCHEDULED OPERATION

1.1 DEFINITION: A Time Scheduled Operation (TSO) function shall be provided to automatically start and stop designated systems based on the time and type of day, according to operator defined schedules.

1.2 OPERATION: The EMCS shall start or stop systems automatically at times designated in schedule data stored within the EMCS. The EMCS shall provide a minimum of 100 independent schedules. Each schedule shall cover a time period of at least one day (24 hours). Each schedule shall provide a minimum of two start times and two stop times per day. Each system designated to be controlled by TSO shall be associated with a minimum of eight independent schedules. Each of these eight shall correspond with a particular type of day. The eight types of days shall be:

1) Sunday	5) Thursday
2) Monday	6) Friday
3) Tuesday	7) Saturday
4) Wednesday	8) Holidays

The EMCS shall automatically determine the type of day and select the schedule associated with that type of day for each system. The EMCS shall start and stop each system designated for TSO control according to the schedule selected for that system.

Provide an adjustable time delay between starting of systems to prevent excessive loading of electrical distribution equipment.

The EMCS shall monitor the ON/OFF status of each system thru differential pressure switches, flow switches, starter contacts or other devices as designated on each system schematic. This status shall be checked at least once every 3 minutes. If the monitored status is not the same as that called for by the EMCS, both an audible and printed alarm shall be given to the operator. Alarms shall not be given for a

system during an adjustable time delay following the issuance of a start or stop control action from the EMCS to that system.

1.3 SYSTEMS INTERFACE:

1.3.1 Input Requirements:

Status contact sensor (differential pressure switch, flow switch, starter contact or other device as called for on the appropriate system schematic).

1.3.2 Output Requirements:

Start/Stop control interface

1.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the TSO function and shall be performed during continuous EMCS operation.

1.4.1 The start and stop times for each schedule shall be adjustable by the operator.

1.4.2 The schedule associated with each day type for each system shall be operator determined and modifiable.

1.4.3 The operator shall designate and change the dates of Holiday day type occurrence.

1.4.4 The time delay between starting of systems by the EMCS shall be operator adjustable and shall have a minimum range of from 0 to 999 seconds.

1.4.5 The time delay of alarm reporting for a particular system following the starting or stopping of that system by the EMCS shall be operator adjustable and shall have a minimum range of from 0 to 999 seconds.

2.0 DUTY CYCLING:

2.1 DEFINITION: A Duty Cycle (DC) function shall be provided which shall automatically stop and start designated systems, based on a repeating time cycle with an operator designated cycle, and system shutdown interval adjusted according to system space temperature.

2.2 OPERATION: The EMCS shall stop operating systems automatically on a repeating cycle basis and restart the systems after a shutdown interval. Cycle interval is the length of time over which repetitive control actions are taken. Shutdown interval is the length of time during a cycle interval that a controlled system is stopped. Nominal cycle intervals of 30, 60, and 120 minutes shall be provided. One of the nominal cycle intervals shall be assigned to each system designated to be controlled by DC. An independent shutdown interval shall be assigned to each system. The shutdown interval shall have a range from zero minutes to the length of the cycle interval assigned to that system. The actual duration of system shutdown shall be determined by the EMCS by adjusting the assigned shutdown interval in response to space temperature. If space temperature conditions are satisfied, the actual shutdown duration shall be increased over the assigned shutdown interval. If space temperature conditions are not satisfied, the actual shutdown duration shall be decreased from the assigned shutdown interval. In addition to the shutdown interval assigned to each system, a minimum shutdown interval and maximum shutdown interval shall be assigned for each system, which shall override the space temperature compensation adjustment of the actual shutdown duration. The EMCS shall automatically adjust the initiation of cycle intervals and the occurrence of the shutdown interval within a cycle interval, to provide a uniform reduction in the rate of electrical energy consumption by systems controlled by the DC function. Each system shall be assigned a weighting factor proportional to the rate of electrical energy consumption associated with that system. The weighting factor, in conjunction with cycle and shutdown interval data, for all systems controlled by DC, shall be used to determine an operation which will provide uniform load reduction.

2.3 SYSTEMS INTERFACE:

2.3.1 Input Requirements:

Status contact sensor (differential pressure switch, flow switch, starter contact or other device as called for on the appropriate system schematic).

Space temperature indication. Provide ability to continue operation of DC function on a system if actual space temperature data is unavailable by using a default value of space temperature in the shutdown interval adjustment actions.

2.3.2 Output Requirements:

Start/Stop control interface

2.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the DC function and shall be performed during continuous EMCS operation.

2.4.1 The systems controlled by the DC function shall be assigned or deleted by the operator.

2.4.2 The nominal cycle interval to be used for each system shall be operator determined and modifiable.

2.4.3 The shutdown interval for each system shall be adjustable by the operator in not greater than one minute increments.

2.4.4 The desired maximum and minimum space temperatures for each system shall be defined by the operator.

2.4.5 The maximum and minimum shutdown intervals for each system for temperature compensation override shall be operator determined.

2.4.6 The weighting factor proportional to electrical load for each system shall be operator adjustable.

2.4.7 The time delay of alarm reporting for a particular system following the starting or stopping of that system by the EMCS shall be operator adjustable and shall have a minimum range of from 0 to 999 seconds.

2.4.8 The operator shall be able to manually suspend DC activities for each system. DC activities shall remain suspended for a particular system until they are manually reactivated by the operator.

2.4.9 The default space temperature value to be used by the DC function, if actual space temperature data is unavailable, shall be operator adjustable for each system.

2.5 FUNCTION INTERACTION: The Duty Cycle function shall be interactive with the Time Scheduled Operation (TSO), Electrical Demand Limiting (EDL), and the Optimized Start/Stop (OSS) functions. DC shall only control a system if that control has been turned over to it by the TSO, EDL, and OSS functions.

2.6 FAILURE MODE: On EMCS failure, systems which have been shut down by the DC function shall be restarted and shall operate under normal local controls. On restart of the EMCS after a failure, systems shall only be controlled under the DC function after that control has been passed to DC from TSO, EDL and OSS functions in an orderly manner.

3.0 ELECTRICAL DEMAND LIMITING

3.1 DEFINITION: An Electrical Demand Limiting (EDL) function shall be provided which shall monitor the rate of electrical energy consumption (demand) measured by utility company demand metering equipment, and shed loads automatically to limit demand below a preset maximum demand target.

3.2 OPERATION: The EMCS shall monitor (#) (power company name) demand meters and shall automatically control loads connected to each meter to limit the peak electrical demand recorded by that meter. Electrical demand is currently defined by (power company name) as ____
____
____
____.

The EMCS shall provide the ability to control at least 500 loads connected to each demand meter for the purpose of demand limiting. The EDL function shall monitor the electrical power consumption rate at the utility company demand meter, predict the resultant demand as defined by the utility company, and take control actions based on the predicted demand to reduce power consumption rate.

The Contractor shall contact (power company name) and arrange for the installation of the necessary demand meter interface equipment and shall pay all charges involved. The EMCS EDL function shall operate with both "sliding window" and fixed interval demand metering systems. When applied to fixed interval metering systems, synchronization with the meter end of interval signal shall be provided. If the meter end of interval signal is absent, the EDL function shall automatically use a sliding window method of demand measurement and return to a fixed interval method, upon recognition of a correct end of interval signal.

The EMCS shall utilize the data monitored at the demand meter to predict the demand at the end of the demand interval. The EDL function shall not use ideal rate or ideal curve methods to predict the

demand. The length of demand interval used in the prediction shall be operator defined and adjustable.

The EMCS shall automatically take control actions to reduce the rate of power consumption whenever the predicted demand exceeds a present maximum demand level. Loads to be controlled shall have independently adjustable maximum and minimum off times and minimum run times. A minimum of 16 priority levels of loads shall be provided. Priority 16 loads shall be controlled first and priority one loads shed last. Loads shall be rotated automatically within each priority level. The EDL function shall take control action throughout the demand interval to eliminate the need for large changes near the end of interval. An adjustable time delay shall be provided between starts to prevent power surges. Reloading of the system at the start of a demand interval shall be based upon the rate of use at the end of the last interval.

The following types of control actions shall be taken by the EDL function:

> START/STOP: Designated systems shall be stopped to reduce predicted demand levels under EDL control using the control sequences and devices indicated on the system schematic. The systems shall be restarted, based on the maximum and minimum off time limits for each system. Once restarted, a system shall not be stopped by the EMCS until the minimum run time for that system has elapsed.
>
> GENERAL OPERATION: Designated generator systems shall be started to reduce predicted electrical demand levels under EDL controls, using the control sequences and devices indicated on the schematic for that system. Each generator shall not be stopped until the minimum run time limit for that generator has been exceeded. Once a generator is shut down by the EMCS, it shall not be restarted until a minimum off time for that generator has elapsed.

CHILLER LIMIT ADJUST: The current limiting controls on the designated centrifugal water chilling systems shall be adjusted to a fixed minimum position to reduce predicted electrical demand levels under EDL control.

3.3 SYSTEM INTERFACE

3.3.1 Input Requirements: For the following control actions:

START/STOP: Status contact sensor (see individual system schematic for type of sensor).

GENERATOR OPERATION: Status contact sensor (see individual generator schematic for method and type of sensor).

CHILLER LIMIT ADJUST: Status contact sensor

3.3.2 Output Requirements: For the following control actions:

START/STOP: Start/Stop control interface.

GENERATOR OPERATION: Start/Stop control interface.

CHILLER LIMIT ADJUST: Current limit minimum position control interface.

3.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the EDL function and shall be performed during continuous EMCS operation.

3.4.1 The demand interval length shall be adjustable by the operator.

3.4.2 Loads shall be assigned to, deleted from, or temporarily disabled from EDL control by the operator. Loads temporarily disabled by the operator shall remain so until specifically reenabled by the operator.

3.4.3 The priority level assigned to a load shall be modifiable by the operator.

3.4.4 The time delay between starting of loads shall be operator adjustable.

3.4.5 Minimum and maximum off times and minimum run time for each load shall be operator adjustable.

3.4.6 The maximum allowable demand level shall be operator adjustable.

3.4.7 On operator request, the EMCS shall display the present demand, power factor, and the demand for the last demand interval.

3.4.8 Any messages (change of state) produced as a result of EDL action shall include a notation indicating the change of state is a result of EDL action.

3.4.9 The EMCS shall produce a daily power utilization report consisting of the following information:

3.4.10 The EMCS shall produce a monthly power utilization report consisting of the following information:

4.0 WARM UP/NIGHT CYCLE

4.1 DEFINITION: A Warm Up/Night Cycle (WUN) function shall be provided which shall control air handling system outside air intake dampers during unoccupied periods.

4.2 OPERATION: The EMCS shall automatically open or close outside air intake dampers, based on the air handling unit status and a schedule of occupancy for the areas served by that unit. The EMCS shall provide a minimum of 100 independent occupancy schedules. Each schedule shall cover a time period of at least one day (24 hours). Each schedule shall provide a minimum of two start occupancy times and two stop occupancy times per day. Each air handling system designated to be controlled by WUN shall be associated with a minimum of eight independent schedules. Each of these eight shall correspond with a particular type of day. The eight types of days shall be:

1)	Sunday	5)	Thursday
2)	Monday	6)	Friday
3)	Tuesday	7)	Saturday
4)	Wednesday	8)	Holidays

The EMCS shall automatically determine the type of day and select the schedule associated with that type of day for each system. The EMCS shall open and close the outside air dampers on each system designated for control according to the schedule selected for that system. Dampers shall be open to the minimum outside air position during occupied hours and shall be closed during unoccupied hours, except dampers shall be closed whenever the air system is shut down.

4.3 SYSTEMS INTERFACE:

4.3.1 Input Requirements:

Status contact sensor on air handling unit operation (see system schematics for sensor type for each individual system).

4.3.2 Output Requirements:

Damper control interruption interface.

4.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the WUN function and shall be performed during continuous EMCS operation.

4.4.1 The occupancy start and occupancy stop times for each schedule shall be adjustable by the operator.

4.4.2 The schedule associated with each day type for each system shall be operator determined and modifiable.

4.4.3 The operator shall designate and change the dates of Holiday day type occurance.

4.5 RELATIONSHIIP TO OTHER APPLICATIONS FUNCTIONS: Damper control by WUN shall be overridden by ENTHALPY ECONOMIZER function operation.

4.6 FAILURE MODE: On EMCS failure, control of dampers shall revert to local analog control systems.

5.0 ENTHALPY ECONOMIZER

5.1 DEFINITION: An Enthalpy Economizer (EE) function shall be provided which shall monitor the enthalpy of the return air for an air handling system, measure the enthalpy of outside air, and then control the outside and return air dampers for that system, based on the air stream which will result in the least cooling energy consumption.

5.2 OPERATION: The EMCS shall automatically switchover outside air damper control to the local cooling control system of an air handling unit whenever the enthalpy of the return air is greater than the enthalpy of the outside air.

5.3 SYSTEMS INTERFACE:

5.3.1 Input Requirements:

Status contact sensor
Return air temperature
Return air relative humidity
Outside air temperature (at one location)
Outside air relative humidity

5.3.2 Output Requirements:

Damper control changeover interface

5.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the EE function and shall be performed during continuous EMCS operation.

5.4.1 The operator shall designate which systems are to be controlled by EE operation.

5.4.2 The operator shall be able to define a deadband between outside and return air enthalpy over which the changeover will take place.

5.5 RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS: The EE function shall override WUN operation.

5.6 FAILURE MODE: On EMCS failure, control of dampers shall revert to local analog control system.

6.0 SPACE NIGHT SETBACK

6.1 DEFINITION: A Space Night Setback (SNS) function shall be provided which shall maintain minimum and maximum space temperatures during system shutdown.

6.2 OPERATION: The EMCS shall automatically start or stop systems at times designated in operation schedule data stored within the EMCS. Systems designated to be controlled by SNS shall have all the capabilities specified under TIME SCHEDULED OPERATION. In addition to these capabilities, the temperature in a space served by a SNS controlled system shall be monitored. If the temperature exceeds a maximum limit or is below a minimum limit, the EMCS shall restart the system serving that space. The system shall operate under its normal local control. The EMCS shall shut down the system after the space temperature has either risen or fallen within an acceptable temperature range.

6.3 SYSTEM INTERFACE:

6.3.1 Input Requirements:

Status contact sensor
Space temperature

6.3.2 Output Requirements:

Start/Stop Control Interface

6.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the SNS function and shall be performed during continuous EMCS operation.

6.4.1 All capabilities specified under paragraph 1.4.

6.4.2 The minimum and maximum space temperatures above and below which the EMCS shall start the system shall be modifiable by the operator.

6.4.3 The space temperature range within which the EMCS shall shutdown a system shall be operator designated.

6.5 RELATIONSHIP TO OTHER APPLICATION FUNCTIONS:

6.5.1 SNS shall override TIME SCHEDULED OPERATION.

6.5.2 WARM UP/NIGHT CYCLE shall override SNS.

7.0 HOT/COLD DECK RESET

7.1 DEFINITION: A Hot/Cold Deck Reset (HCR) function shall be provided which shall adjust hot and/or cold supply air temperatures such that the temperature will coincide with the need for heating and/or cooling.

7.2 OPERATION: The EMCS shall adjust the setpoint of local supply air temperature controllers to the position which will exactly satisfy the zone having the greatest demand.

7.3 SYSTEMS INTERFACE:

7.3.1 Input Requirements:

Status Contact Sensor
Greatest demand selector
Return air relative humidity
Supply air temperature

7.3.2 Output Requirements:

Supply air temperature controller reset interface.

7.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the HCR function and shall be performed during continuous EMCS operation.

7.4.1 The operator shall designate systems to be controlled by the HCR function.

7.5 RELATIONSHIP TO OTHER FUNCTIONS: The HCR function shall operate independently of other EMCS applications functions, except that HCR shall not reset controller setpoints of systems not operating.

7.6 FAILURE MODE: On EMCS failure, the supply air temperature controllers under HCR control shall remain at the setpoint position where they were at the time of EMCS failure.

8.0 CHILLED WATER RESET

8.1 DEFINITION: A Chilled Water Reset (CWR) function shall be provided which shall adjust chilled water system temperatures such that the temperature will coincide with the need for cooling.

8.2 OPERATION: The EMCS shall adjust the setpoint of local chilled water temperature controllers to the position which will exactly satisfy the greatest demand for cooling.

8.3 SYSTEMS INTERFACE:

8.3.1 Input Requirements:

Contact Status Sensor
Chilled Water Supply Temperature
Chilled Water Return Temperature

8.3.2 Output Requirements:

Controller Reset Interface

8.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the CWR function and shall be performed during continuous EMCS operation.

8.4.1 The operator shall designate systems to be controlled by the CWR function.

8.4.2 The EMCS shall display chilled water supply and return temperature and controller setpoint at operator request.

8.5 RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS: The CWR function shall operate independently of the other EMCS applications functions, except that CWR shall not reset controller setpoints of systems not operating.

8.6 FAILURE MODE: On EMCS failure, chilled water temperature controllers under CWR control shall remain at the same setpoint position as that at the time of EMCS failure.

9.0 CONDENSER WATER RESET

9.1 DEFINITION: A Condenser Water Reset (CDR) function shall be provided which shall adjust condenser water system temperature so that the temperature will coincide with the minimum condenser water temperature that can be produced from outside ambient conditions.

9.2 OPERATION: The EMCS shall adjust set point of local condenser water temperature controllers to the position which will produce the lowest condenser water temperature producible from ambient conditions in accordance with current cooling demand.

9.3 SYSTEMS INTERFACE:

9.3.1 Input Requirements:

Contact Status Sensor

Condenser water supply temperature

Condenser water return temperature

9.3.2 Output Requirements:

Controller reset interface

9.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the CDR function and shall be performed during continuous EMCS operation.

9.4.1 The operator shall designate systems to be controlled by the CDR function.

9.4.2 The EMCS shall display condenser water supply and return temperatures and controller setpoint at operator request.

9.5 RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS: The CDR function shall operate independently of other EMCS applications functions, except that CDR shall not reset controller setpoints of systems not operating.

9.6 FAILURE MODE: On EMCS failure, the condenser water temperature controllers under CDR control shall remain at the same setpoint position as that at the time of EMCS failure.

10.0 OUTSIDE AIR SCHEDULE RESET

10.1 DEFINITION: An Outside Air Schedule Reset (OAR) function shall be provided which shall adjust controller setpoint positions linearly in response to outside air temperature.

10.2 OPERATION: The EMCS shall adjust the setpoint of local controllers in proportion to changes in outside air temperature.

10.3 SYSTEMS INTERFACE

10.3.1 Input Requirements:

Contact Status Sensor

Hot water supply temperature

Hot water return temperature

Outside air temperature (in a single location)

10.3.2 Output Requirements:

Controller reset interface

10.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the OAR function and shall be performed during continuous EMCS operation.

10.4.1 The operator shall designate systems to be controlled by the OAR function.

10.4.2 The EMCS shall display hot water supply and return temperatures and controller setpoint at operator request.

10.4.3 The operator shall designate two outside air temperatures and a corresponding controller setpoint and the EMCS shall linearly interpolate between these two input values. These input values shall be used as in points for the controller reset operation and temperatures outside the range shall have no effect on controller setpoint.

10.5 RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS: The OAR function shall operate independently of other EMCS applications functions except that OAR shall not reset controller setpoints of systems not operating.

10.6 FAILURE MODE: On EMCS failure, the hot water temperature controllers under OAR control shall remain at the setpoint position they were at at the time of the EMCS failure.

11.0 START/STOP OPTIMIZATION

11.1 DEFINITION: A Start/Stop Optimization (SSO) function shall be provided which shall automatically start and stop designated systems based on a calculated optimum start time and stop time.

11.2 OPERATION: The EMCS shall start systems designated to operate under SSO control at times calculated by the EMCS necessary to start the system in order for certain temperature limits to be reached before building occupancy.

11.3 SYSTEMS INTERFACE

11.3.1 Input Requirements:

Status Contact Sensor

Inside space temperature

Outside air temperature (at a single location)

11.3.2 Output Requirements:

Start/Stop Control Interface

11.4 OPERATOR INTERFACE: The following operator related activities shall be provided in conjunction with the SSO function and shall be performed during continuous EMCS operation:

11.4.1 All operator related activities specified in paragraph 1.4 shall be provided for SSO operation.

11.4.2 The operator shall designate systems to be controlled by the SSO function.

II.5 RELATIONSHIP TO OTHER APPLICATIONS FUNCTIONS: The SSO function shall override time scheduled operation function operations for systems assigned to SSO.

II.6 FAILURE MODE: On EMCS failure, systems assigned to SSO control shall revert to conventional local controls.